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TECHNICAL MEMORANDUM NO 3

HUMAN HEALTH RISK ASSESSMENT
WALNUT CREEK PRIORITY DRAINAGE
OPERABLE UNIT NO 6
MODEL DESCRIPTION

DRAFT FINAL

ROCKY FLATS PLANT

U S DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado

ENVIRONMENTAL MANAGEMENT DEPARTMENT

July 1993

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This document provides a description of the models selected to perform groundwater, surface-water, and air modeling for Rocky Flats Plant Operable Unit No 6 (OU6) in support of the Human Health Risk Assessment (risk assessment), which is part of the OU6 Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) This document does not describe the details of the implementation of selected models to the site-specific conditions at OU6, that will be described in detail in the Phase I RFI/RI Report

The objective of the modeling is to support the Human Health Risk Assessment portion of the RFI/RI Report for OU6 This will be accomplished by simulating the transport of chemicals of concern from OU6 to potential exposure points for human receptors under present and anticipated future site conditions

A conceptual site model (CSM) has been developed to identify and evaluate the chemical source areas, chemical release mechanisms, environmental transport media, potential human intake routes, and potential human receptors at OU6. The purpose of the CSM is to identify human exposure pathways to be quantitatively evaluated in the Human Health Risk Assessment Exposure pathways chosen for evaluation in the risk assessment that include transport media such as groundwater, surface-water, and air, may require fate and transport modeling to estimate chemical exposure point concentrations The following document describes the exposure pathways to be evaluated in the Human Health Risk Assessment that will require such modeling and identifies the mathematical models that will be used to estimate exposure point concentrations The models are based on data that have been collected at the site as part of the Phase I RFI/RI for OU6 At the time this technical memorandum was prepared, only a portion of the soil and groundwater data from the Phase I investigation were available If additional data that are substantially different than those used in developing this technical memorandum become available, revisions to the modeling approach may become necessary

The following models were selected to meet the requirements and objectives of the modeling study

- The ONED3 analytical model for groundwater contaminant fate and transport Also, water balance and chemical mass balance analyses to evaluate contaminant fate and transport

- The watershed/water quality model HSPF9 for surface-water fate and transport

- The Superfund Exposure Assessment Manual (SEAM) Models for soil gas fate and transport, a box model for on-site ambient air contaminant fate and transport, and Fugitive Dust Model (FDM) for off-site ambient air contaminant fate and transport of OU6 source air emissions

Data available for use as input for the modeling activities were evaluated based on a review of previous and ongoing investigations, and general literature. Tables 3-1, 3-2, 3-3, and 3-4 summarize the data currently available to estimate model input parameters Additional data from the Phase I RFI/RI investigation will be used in the modeling effort once those data become available

The data presented in Tables 3-1, 3-2, 3-3, and 3-4 are preliminary and, in some cases, are not site specific The data values or ranges of values are not intended to be fixed or final The ranges are presented to convey what is currently known of the potential variability in the parameter values that may be used in the models

1.0
INTRODUCTION

This document provides a description of the models selected to perform groundwater, surface water, and air modeling for the OU6 Human Health Risk Assessment The results of the modeling will be used as exposure point concentrations in the Human Health Risk Assessment, which is part of the OU6 Phase I RCRA RFI/RI The RFI/RI is being conducted pursuant to the Compliance Agreement between the U S Department of Energy (DOE), the U S Environmental Protection Agency (EPA), and the State of Colorado Department of Health (CDH), dated July 31, 1986, and the Federal Facility Agreement and Consent Order (FFACO) [known as the Inter-Agency Agreement (IAG)], dated January 22, 1991 The DOE Environmental Restoration Program (ERP) was formed to identify, investigate, and if necessary, remediate contaminated sites at DOE facilities The program, in fulfilling this mission, addresses RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) issues In accordance with the IAG, the CERCLA terms "Remedial Investigation" and "Feasibility Study" in this document are considered equivalent to the RCRA terms "RCRA Facility Investigation" and "Corrective Measures Study," respectively

This technical memorandum is intended for review in conjunction with the Human Health Risk Assessment Exposure Scenarios Technical Memorandum for OU6 (DOE 1993) The reader of this technical memorandum is referred to that document for additional information or details on the exposure scenarios to be used for OU6

The remainder of Section 1 0 includes a discussion of the purpose of this technical memorandum, the objectives of the modeling activities (Section 1 1), and a brief description of the site location and general site conditions (Section 1 2) Section 2 0 presents the conceptual site model and exposure pathways to be evaluated in the risk assessment for OU6, and Section 3 0 presents descriptions of the selected models for groundwater, surface water, and air, and a summary of model input parameter values Section 4 0 presents a summary, and Section 5 0 is a list of references used in preparing this technical memorandum

1.1 PURPOSE AND SCOPE

The purpose of this document is to provide a description of appropriate groundwater, surface water, and air models for use at OU6 This document fulfills the IAG requirements (IAG 1991, Section VII D 1 b) that state

" DOE shall submit for review and approval a description of the fate and transport models that will be utilized, including a summary of the data that will be used with these models Representative data shall be utilized, and the limitations, assumptions and uncertainties associated with the models shall be documented "

The model selection process focuses on models appropriate for simulating processes affecting the migration of contaminants through the saturated zone, the unsaturated zone, surface water, and the airborne transport of contaminants Model selection is based on the general site conditions outlined in this document and in the Phase I RFI/RI Work Plan for OU6 (DOE 1992a) Site-specific data will be incorporated into the models

Modeling activity quality assurance is covered by the site-wide quality assurance plan (EG&G 1991a) Modeling quality assurance (QA) includes model verification, checks on calculations, and technical review of modeling methods, assumptions, results, and interpretations

The objective of the modeling is to support the Human Health Risk Assessment portion of the RFI/RI Report for OU6 This will be accomplished by simulating the transport of chemicals of concern from OU6 to potential exposure points for human receptors under present and anticipated future site conditions

1.2 SITE LOCATION AND GENERAL SITE CONDITIONS

The Rocky Flats Plant (RFP) is a government-owned and contractor-operated facility that is part of the nationwide nuclear weapons production complex RFP was operated for the U S Atomic Energy Commission (AEC) from the RFP's inception in 1951 until the AEC was dissolved in January 1975 At that time, responsibility for RFP was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by DOE in 1977 Dow Chemical USA, an operating unit of The Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975, when it was succeeded by Rockwell International On January 1, 1990, EG&G Rocky Flats, Inc succeeded Rockwell International

RFP's primary mission has been to produce metal components for nuclear weapons These components are fabricated from plutonium, uranium, and nonradioactive metals (principally beryllium and stainless steel) Current waste handling practices involve on-site and off-site recycling of hazardous material, on-site storage of hazardous and radioactive mixed wastes, and disposal of solid radioactive materials at another DOE facility However, historically, the operating procedures included both on-site storage and disposal of hazardous and radioactive wastes Preliminary assessments under the ERP identified some of the past on-site storage and disposal locations as potential sources of environmental contamination

RFP is located on 6,550 acres of federally owned land in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 1-1) Surrounding cities include Boulder, Broomfield, Superior, Westminster, and Arvada, which are located less than ten miles to the northwest, east, and southeast Within RFP is a Protected Area (PA) or security area surrounded by a buffer zone of approximately 6,150 acres A general description of RFP is presented in this section For a more detailed description, please refer to the RFI/RI Work Plan for OU6 (DOE 1992a)

This Phase I RFI/RI modeling technical memorandum addresses OU6, which is the Walnut Creek Priority Drainage located north and east of the RFP security area Figure 1-2 shows the locations of this area, and the IHSSs within OU6 The following sites are designated as IHSSs at OU6

- A-series ponds (IHSSs 142 1, 142 2, 142 3, and 142 4)
- B-series ponds (IHSSs 142 5, 142.6, 142 7, 142 8, and 142 9)
- Pond at the intersection of Walnut Creek and Indiana Street (IHSS 142 12)
- North, Pond and South Area Spray Fields (IHSSs 167 1, 167 2, and 167 3)
- Trenches A, B, and C (IHSSs 166 1, 166 2, and 166 3)
- Old Outfall (IHSS 141)
- Sludge Dispersal Area (IHSS 143)
- Triangle Area (IHSS 165)
- Soil Dump Area (IHSS 156 2)
- East Spray Field (IHSS 216 1)

A more detailed description of each IHSS and the types of associated contamination can be found in the Phase I RFI/RI Work Plan for OU6 (DOE 1992a)

1.2.1 Physical Setting

The natural environment of RFP and its vicinity is influenced primarily by its proximity to the Front Range of the Rocky Mountains RFP is directly east of the north-south trending Front Range and is located approximately sixteen miles east of the Continental Divide, on a broad, eastward-sloping plain of coalescing alluvial fans developed along the Front Range at an elevation of approximately 6,000 feet above mean sea level The fans extend approximately five miles in an eastward direction from their origin at Coal Creek Canyon and terminate on the east, at a break in the slope, as low rolling hills The operational area at RFP is located near the eastern edge of the fans on a terrace between stream-cut valleys (North Walnut Creek and Woman Creek)

Three intermittent streams drain RFP with flow generally from west to east These drainages are Rock Creek, Walnut Creek, and Woman Creek. Rock Creek drains the northwestern corner of RFP and flows northeast through the buffer zone to its off-site confluence with Coal Creek North and South Walnut Creeks and an unnamed tributary drain the northern portion of the RFP Protected Area These three forks of Walnut Creek join in the buffer zone and flow toward Great Western Reservoir, which is approximately one mile east of the confluence This flow is currently routed around Great Western Reservoir by the Broomfield Diversion Canal operated by the City of Broomfield Woman Creek drains the southern RFP buffer zone and flows eastward to Standley Reservoir OU6 is the Walnut Creek drainage and is bounded on the north by the unnamed tributary to Walnut Creek and on the south by the land south of the B-series ponds on South Walnut Creek

1.2.2 Meteorology

In general, winds blow from northerly through westerly directions approximately 64 percent of the year Southerly wind directions occur with less frequency (approximately 20 percent of the year), while easterly wind directions are infrequent (only 11 percent of the year) Wind patterns are heavily influenced by synoptic scale meteorological patterns, convective storms, and mountain/valley flows

The wind speeds are greatest from the northwesterly direction Wind speeds in excess of 15 meters per second (34 miles per hour) are regularly observed Winds are calm approximately 5 percent of the year Figure 1-3 presents a wind rose illustrating wind patterns in the region for the year 1990 This wind rose is generated from wind speed and direction data recorded at an on-site meteorological tower at a monitoring height of 61 meters

Atmospheric stability at the site is generally neutral (Class D) to slightly stable (Class E) Periods of very stable (Class F) and unstable (Class A through C) stability occur less than 20 percent of the year (DOE 1992b) Neutral to slightly stable conditions generally allow for uniform dispersion of contaminants Very stable atmospheric conditions inhibit dispersion Unstable atmospheric conditions aid in dispersing contaminants

Precipitation at the Rocky Flats Plant averages 380 millimeters (15 inches) per year A majority of the precipitation is in the form of snowfall and occurs during the winter and spring seasons Average annual total snowfall is 2160 millimeters (85 inches) The summers are generally dry with isolated thunderstorms contributing up to 30 percent of the annual precipitation Autumn is the driest period of the year Annual potential free-water evaporation is approximately 1144 millimeters (45 inches) which is significantly greater than the annual precipitation (DOE 1992b)

1.2.3 Geology

The near-surface geologic materials at RFP consist of surficial unconsolidated deposits and shallow bedrock The surficial deposits at OU6 consist of pediment alluvium, colluvium, valley fill alluvium, and artificial fill that unconformably overlay bedrock (Figure 1-4) Surficial deposits at RFP are Quaternary (Pleistocene-Holocene) in age Near-surface bedrock consists of the Arapahoe and Laramie Formations, which are Cretaceous in age The regional dip of the bedrock in the vicinity of OU6 in approximately two degrees to the east

The Rocky Flats Alluvium is a pediment gravel deposited in a laterally coalescing alluvial fan environment It was deposited across a gently sloping erosional surface cut into the underlying soft bedrock The deposit consists of poorly to well sorted, poorly stratified clays, silts, sands, gravels and cobbles The colors of the Rocky Flats Alluvium include light to dusky brown, dark yellowish-orange, grayish orange, dark gray and dusky red The Rocky Flats Alluvium ranges in thickness from 0 to 25 feet beneath OU6 Subsequent dissection and headward erosion by North and South Walnut Creeks, as well as the unnamed northern tributary to Walnut Creek, have cut through the alluvium into the underlying bedrock Remnants of younger terrace deposits of the Verdos and Slocum Alluviums occur at lower elevations in some locations along the valley slopes of OU6

Colluvial materials in OU6 were derived from slope wash and creep of the Rocky Flats Alluvium, and the Arapahoe and Laramie Formations The colluvium consists of clays, sands, and gravels, and ranges in thickness from a few feet to 20 feet Colluvium derived from the Rocky Flats Alluvium characteristically covers the alluvial/bedrock contact along the hillsides Artificial fill and disturbed ground occur in the localized areas of the Old Outfall Area (IHSS 143), the Triangle Area (IHSS 165), the Soil Dump Area (IHSS 156 2), and Trenches A, B, and C (IHSS 166) Recent valley-fill alluvium occurs in the active stream channels of North and South Walnut Creeks, as well as the unnamed northern tributary to Walnut Creek This material is derived from reworked older alluvial, colluvial and bedrock deposits

The Cretaceous-age Arapahoe Formation is the uppermost bedrock formation and unconformably underlies the unconsolidated material at OU6 The Arapahoe Formation is the product of a fluvial depositional environment and is composed of channel, point bar, and overbank fluvial deposits of sandstones, claystones, siltstones and occasional lignitic coal seams and ironstones Formation thickness varies, but maximum thickness is approximately 270 feet beneath the plant (DOE 1992a) The Arapahoe Formation outcrops at certain locations along the North and South Walnut Creeks, as well as the unnamed northern tributary to Walnut Creek stream valleys

The Laramie Formation is Cretaceous in age and gradationally underlies the Arapahoe Formation at OU6 The Laramie Formation, which is approximately 700 feet thick (DOE 1992a) in the vicinity of RFP, is divided into two units The lower unit, which is approximately 250 feet thick, is composed of several sandstone layers and many coal seams The upper unit, which is approximately 550 feet thick, is composed of deltaic claystones, siltstones, some fluvial sandstones, and an occasional coal layer The sandstones in the lower unit are light to medium gray, fine to coarse grained, poorly sorted and subangular The upper unit claystones and siltstones are light olive gray to olive-black in color with some carbonaceous material

1.2.4 Hydrogeology

Groundwater encountered beneath OU6 occurs in the Rocky Flats Alluvium, colluvium, valley fill and subcropping sandstone of the Arapahoe Formation In general, groundwater exists under unconfined conditions, however partially confining conditions may exist in portions of the Arapahoe Formation sandstones that are bounded laterally or vertically by claystone Groundwater flow in the Rocky Flats Alluvium is generally from the west to the east, and locally follows the erosional lows on the top of the underlying bedrock Groundwater flow in the sandstone is generally from the west to east on a large scale, by may be locally controlled by the geometry of the sandstone body Groundwater in the colluvium mantling the valley slope south of South Walnut Creek in OU6 has localized flow from seeps

Infiltration of precipitation is the primary source for groundwater recharge Groundwater levels vary in response to seasonal changes Groundwater levels reach their highest levels during the spring and early summer, when precipitation is high and evapotranspiration is low During the remainder of the year, groundwater levels decline with periodic changes due to precipitation events Many alluvial wells go dry during these periods of low water levels Approximately one-half of the alluvial wells completed during the Phase I field investigation (September 1992 through March 1993) were dry following completion

Groundwater discharge from the Rocky Flats Alluvium occurs at seeps on the hillsides, where the alluvium outcrop or subcrop appears along the valleys of North and South Walnut Creeks The seeps occur at the contact between the Rocky Flats Alluvium and underlying bedrock This water then flows downslope along the ground surface or through colluvial deposits to the North and South Walnut Creeks, as well as the unnamed northern tributary of Walnut Creek

1.2.5 Surface Water Hydrology

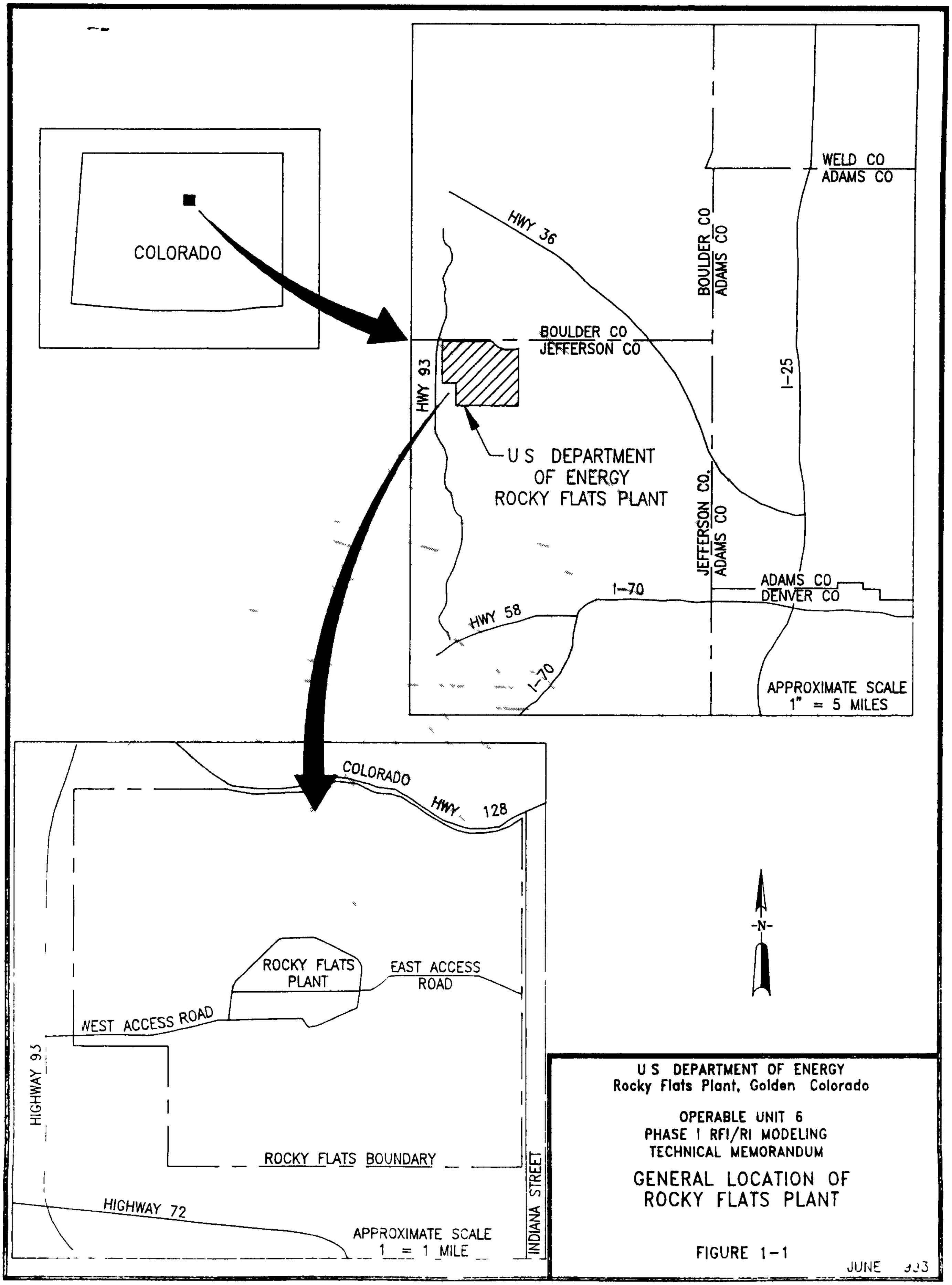
The Rocky Flats Plant is located on a plateau which is bounded on the north by North Walnut Creek North and South Walnut Creeks are intermittent streams that receive surface runoff from the northern and eastern portion of the Plant facility and adjoining buffer zone An unnamed tributary (located 1/2 mile north of the facility and north of North Walnut Creek) receives surface runoff from the northern buffer zone All three of these creeks merge into Walnut Creek within the buffer zone about 1 mile northeast of the Protected Area (PA) (Figure 1-2) Walnut Creek flows toward Great Western Reservoir, located approximately 1/3 mile east of the eastern boundary (Indiana Street) of the Rocky Flats Plant The water from Walnut Creek is diverted around Great Western Reservoir by the Broomfield Diversion Ditch and is carried to Big Dry Creek

The headwaters of North Walnut Creek originate within the Upper Church Ditch, approximately 1 1/2 miles west of Highway 93, near Coal Creek. South Walnut Creek originates near the center of the Rocky Flats Plant security area and bisects the eastern half of the security area South Walnut Creek converges with North Walnut Creek approximately one mile east of the eastern boundary of the main security area The original headwaters of South Walnut Creek were backfilled during construction of the Plant's facilities, therefore, flow begins near a buried culvert west of Building 991

The four A-series detention ponds (Ponds A-1 through A-4) have been built in North Walnut Creek, northeast of the main security area of the Plant facility (Figure 1-2) Surface water in North Walnut Creek flows eastward in its original channel to just west of Pond A-1 The A-1 Bypass diverts this runoff around Ponds A-1 and A-2 and channels it into Pond A-3, where the water is temporarily detained Currently Ponds A-1 and A-2 receive no upstream runoff from North Walnut Creek These ponds are used primarily for spill control management and to detain runoff from the area immediately adjacent to these ponds The water collected in Ponds A-1 and A-2 is not released downstream but is disposed of through spray and pond evaporation Pond A-3 receives surface water from North Walnut Creek and runoff form the northern production facilities via the A-1 Bypass Periodically, water in Pond A-3 is transferred into

Pond A-4 The water in Pond A-4 is treated by a granular activated-carbon (GAC) system before being discharged into North Walnut Creek Downstream of Pond A-4 and west of Indiana Street, water from Walnut Creek is temporarily detained in a pond, IHSS 142 12, until it reaches a high enough level to flow out and downstream into Walnut Creek toward Great Western Reservoir The water in Walnut Creek is diverted around Great Western Reservoir by the Broomfield Diversion Ditch, which caries water to Big Dry Creek

The B-series detention ponds (Ponds B-1 through B-5) have been built in South Walnut Creek east of the main security area of the Plant facility (Figure 1-2) Ponds B-1 and B-2 are primarily used for spill control management and to detain surface runoff from the upstream portion (eastern part) of the facility The water collected in these ponds is not discharged downstream but disposed of through spray field evaporation similar to Ponds A-1 and A-2 Pond B-3 receives effluent from the Sewage Treatment Plant (STP) (Building 995) and local surface runoff Water in Pond B-3 is continuously discharged to Pond B-4 Water in Pond B-4 is continuously released to Pond B-5. Pond B-5 receives water from Pond B-4 and, occasionally, receives water from surface runoff from the Central Avenue Ditch located south of the B-series Ponds This ditch receives surface runoff that originates near the eastern production facilities The water in Pond B-5 is not discharged to South Walnut Creek but is periodically pumped to Pond A-4, where the water is treated through a GAC system before being discharged downstream to Walnut Creek.



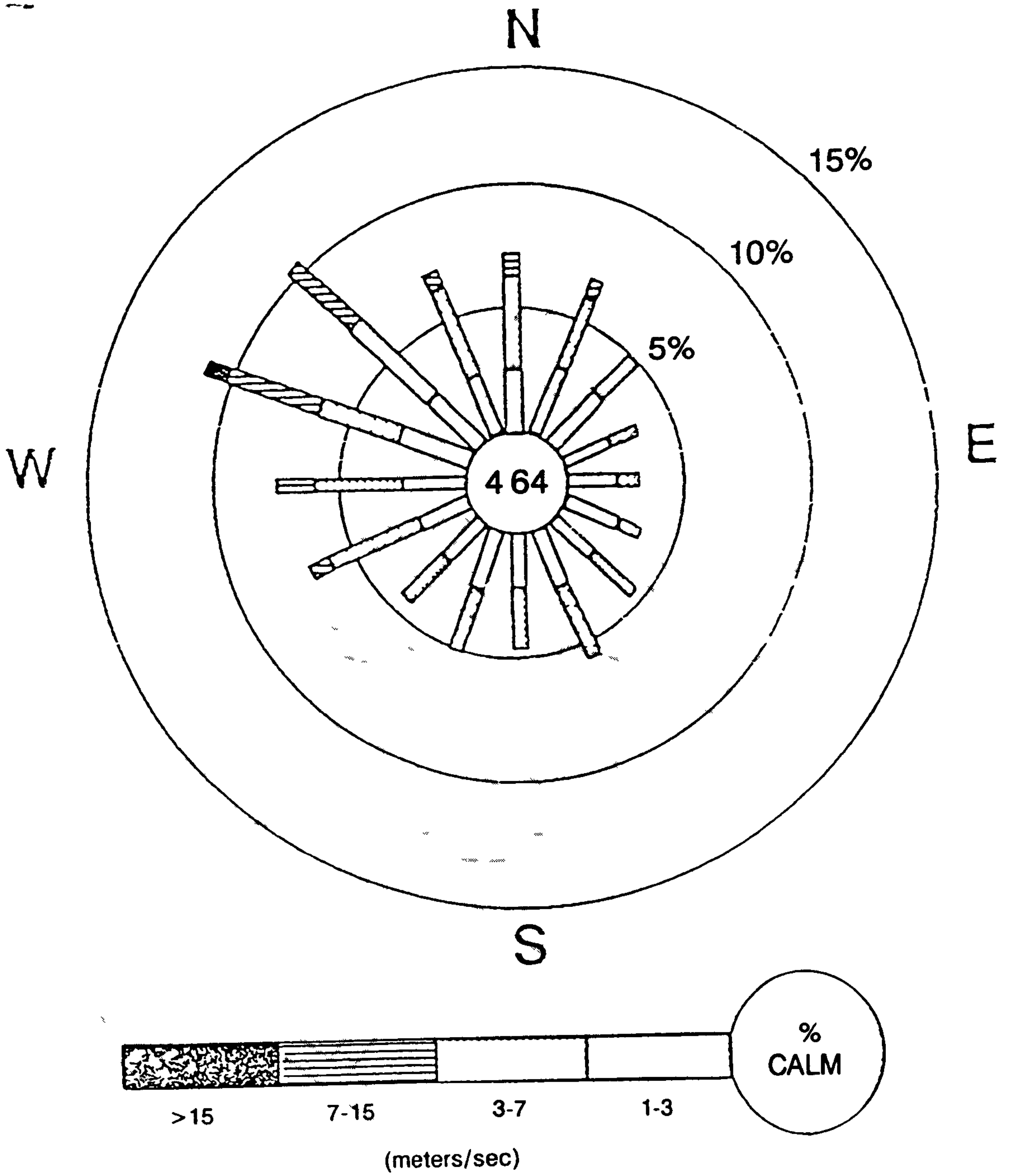
U S DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden Colorado

OPERABLE UNIT 6
PHASE I RFI/RI MODELING
TECHNICAL MEMORANDUM

GENERAL LOCATION OF
ROCKY FLATS PLANT

FIGURE 1-1

JUNE 993



SOURCE EG&G 1991b

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OPERABLE UNIT 6
PHASE I RFI/RI MODELING
TECHNICAL MEMORANDUM

WIND ROSE FOR THE
ROCKY FLATS PLANT
1990 ANNUAL

FIGURE 1-3

JUNE 1993

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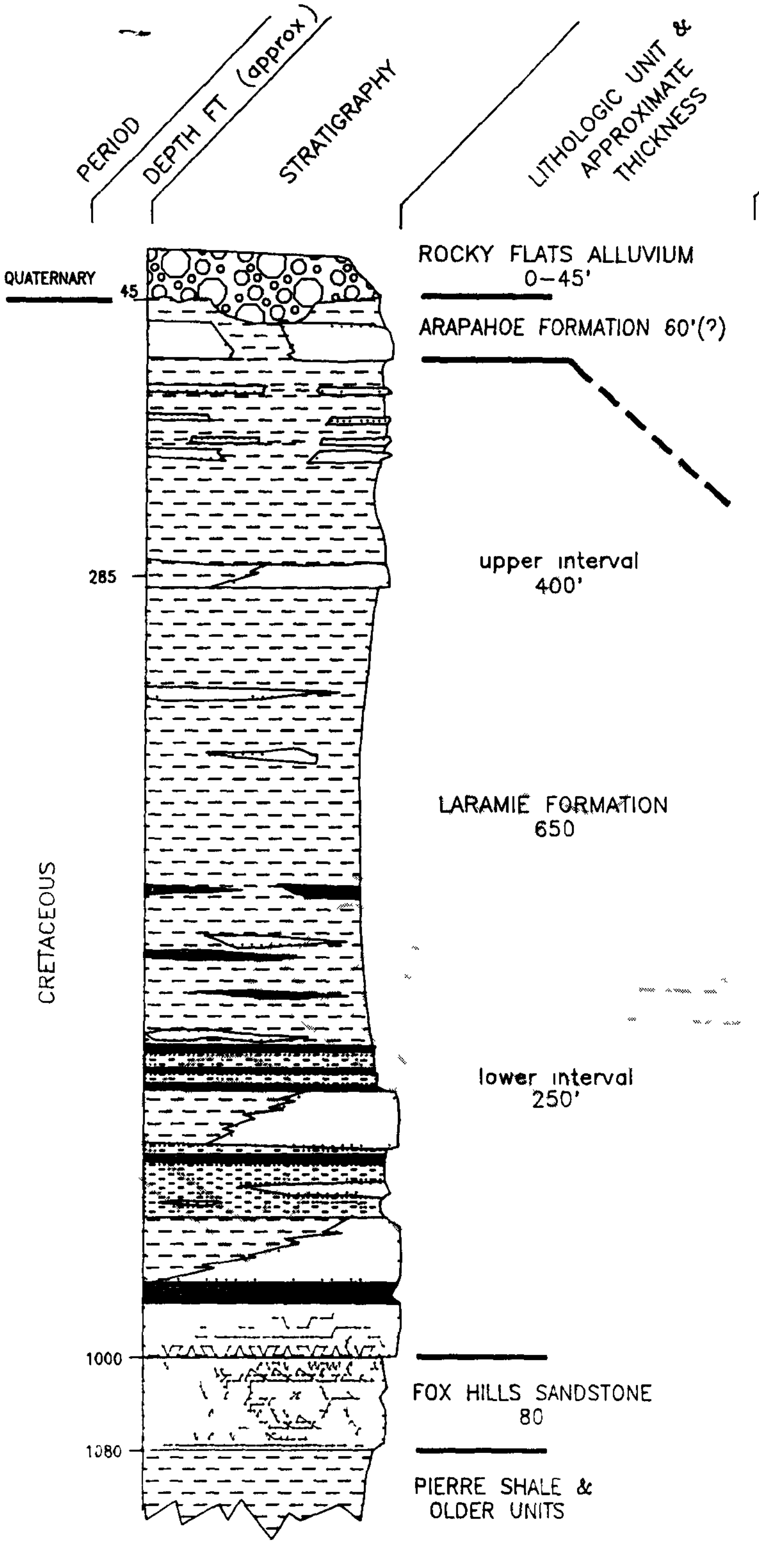


CLAYEY SANDY GRAVELS–
light brown to yellowish–orange, grayish–orange to dark gray, poorly sorted, angular to subrounded, cobbles, coarse gravels coarse sands and gravelly clays varying amounts of caliche

CLAYSTONE SILTSTONES, CLAYEY SANDSTONES, SANDSTONE–
light to medium olive–gray with some dark olive–black claystone and silty claystone Weathered intervals may be yellowed, and basal sand is often conglomeratic

CLAYSTONES, SILTSTONES, AND COAL–
kaolinitic, light to medium gray claystone and siltstone and some dark gray to black carbonaceous claystone, thin (2') coals and thin discontinuous very fine–to–medium grained moderately sorted sandstone intervals

SANDSTONES
light to medium gray, fine–to coarse–grained, poorly–to moderately–sorted silty, immature quartzitic sandstone with numerous lenticular, sub–bituminous coal beds and seams that range from 2 thick in the upper lower interval to 8' thick at the base of the lower interval

SANDSTONES–
grayish–orange to light gray calcareous, fine–grained, subrounded, glauconitic feldspathic, friable sandstone

EXPLANATION

ALLUVIUM	SILTSTONE & CLAYSTONE
FINE–GRAINED & COARSER SANDSTONE	COAL
FINE GRAINED SANDSTONE	SILTY SANDSTONE

. . E FROM LEROY AND WEIMER 1971 AND WEIMER 1973

U S DEPARTMENT OF ENERGY
Rocky Flats Plant Golden, Colorado

OPERABLE UNIT 6
PHASE I RFI/RI MODELING
TECHNICAL MEMORANDUM

NEAR SURFACE
STRATIGRAPHIC SECTION

FIGURE 1–4

JUNE 1993

23066E04

2.0
GENERAL CONCEPTUAL MODEL OF OPERABLE UNIT 6

2.1 CONCEPTUAL SITE MODEL

This section discusses the potential release and transport of chemicals from OU6 and describes pathways by which the receptor populations may be potentially exposed to chemicals of concern An exposure pathway describes a specific environmental pathway by which an individual can be exposed to chemical constituents present at or originating from a site An exposure pathway includes five necessary elements

- A source of chemicals
- A mechanism of chemical release
- An environmental transport medium
- An exposure point
- A human intake route

Each one of these five elements must be present for an exposure pathway to be complete An incomplete pathway means that no human exposure can occur Only potentially complete pathways will be addressed in the Human Health Risk Assessment for OU6

An exposure point is a specific location where human receptors can come in contact with site-related chemicals The objective of this technical memorandum is to identify fate and transport models that will be used to calculate exposure point concentrations for the Human Health Risk Assessment Environmental media that may transport chemicals of concern from OU6 to potential human exposure points are presented in the conceptual site model for OU6 (Figure 2-1) The media associated with exposure pathways that will require fate and transport modeling are discussed in the following subsections A more detailed summary of potentially exposed human receptor populations and exposure pathways for OU6 is presented in the Human Health Risk Assessment Exposure Scenarios technical memorandum (DOE 1993)

Potentially exposed receptor populations selected for quantitative assessment in the Human Health Risk Assessment include the following

- Current off-site resident
- Current on-site worker (security)

- Future on-site worker (office)
- Future on-site worker (construction)
- Future on-site ecological researcher
- Future off-site resident
- Hypothetical future on-site resident

Exposure points were selected for each of the above receptors so that the reasonable maximum exposures will be quantitatively evaluated Evaluation of potential health risks for receptors at these points will bound the risks for receptors at other exposure points not selected for quantitative evaluation The following exposure points were selected for the receptors identified above These locations are also presented in Figure 2-2

<u>**Current Use Scenarios**</u>

- <u>Off-site residential receptor</u> Nearest downwind residence to RFP (located near the southeast corner of the RFP property boundary)

- <u>On-site occupational receptor</u> Security specialist conducting rounds within the OU6 area

<u>**Future Use Scenarios**</u>

- <u>On-site occupational receptor.</u> Office worker working in a building inside the existing security area or in future office buildings in the buffer zone within OU6

- <u>On-site construction worker</u> Excavation worker preparing foundations for new buildings within OU6 both inside the security area and in the buffer zone

- <u>Ecological researcher</u> Outdoor on-site exposure, within buffer zone area of OU6, bounded by the unnamed tributary to Walnut Creek and South Walnut Creek

- <u>Off-site residential receptor</u> Hypothetical off-site residence at the point at which Walnut Creek intersects the eastern Rocky Flats property boundary (Indiana Street)

- <u>On-site residential receptor</u> Hypothetical on-site residence within the OU6 area

Exposure pathways to be quantitatively evaluated in the Human Health Risk Assessment were identified using a conceptual site model (CSM)(Figure 2-1) The CSM is a schematic representation of the chemical source areas, chemical release mechanisms, environmental transport media, potential human intake routes, and potential human receptors The purpose of the CSM is to provide a framework for problem definition, to identify exposure pathways that may result in human health risks, to aid in identifying data gaps, and to aid in identifying effective cleanup measures, if necessary, that are targeted at significant contaminant sources and exposure pathways

In the CSM, potentially complete and significant exposure pathways are designated by a black dot Potentially complete but relatively insignificant exposure pathways are designated by an open circle Both significant and relatively insignificant exposure pathways will be quantitatively addressed in the risk assessment Quantitatively addressing significant and relatively insignificant exposure pathways will result in risk estimates that do not underestimate actual potential risks Negligible exposure pathways and incomplete exposure pathways are designated in the CSM by an N and a dash, respectively, and will not be addressed in the risk assessment For more detailed description of the pathways, along with their assumptions, please see the Human Health Risk Assessment Exposure Scenarios technical memorandum (DOE 1993)

A summary of potentially complete exposure pathways that will be quantitatively evaluated in the Human Health Risk Assessment is presented in Table 2-1 Those exposure pathways are consistent with CSM shown in Figure 2-1 Exposure pathways that will require fate and transport modeling are those that include groundwater, surface water, and air as transport media to exposure points These include the following exposure pathways

<u>Current Off-site Resident</u>

- Inhalation of airborne particulates
- Soil ingestion (following deposition of airborne particulates on residential soil)
- Dermal contact with soil (following deposition of airborne particulates)
- Ingestion of garden produce (following surface deposition of particulates)

<u>Current On-site Worker</u>

- Inhalation of airborne particulates
- Soil ingestion
- Dermal contact with soil

- External irradiation

Future On-site Office Worker

- Inhalation of volatile compounds released from subsurface soil or groundwater to indoor air
- Inhalation of airborne particulates
- Soil ingestion
- Dermal contact with soil
- External irradiation

Future On-Site Construction Worker

- Inhalation of airborne particulates
- Soil ingestion
- Dermal contact with soil
- External irradiation

Future On-site Ecological Researcher:

- Surface water ingestion (suspended sediment and site-related chemicals potentially transported to surface water)
- Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water)
- Inhalation of airborne particulates
- Soil ingestion
- Dermal contact with soil
- External irradiation

Future Off-Site Resident

- Surface water ingestion (suspended sediment and site-related chemicals potentially transported to surface water)
- Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water)
- Inhalation of airborne particulates
- Soil ingestion (following deposition of airborne particulates on residential soil)

- Dermal contact with soil (following deposition of airborne particulates)
- Ingestion of garden produce contaminated by airborne particulates

Hypothetical Future On-site Resident

- Surface water ingestion (suspended sediment and site-related chemicals potentially transported to surface water)
- Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water)
- Inhalation of volatile compounds released from subsurface soils and/or groundwater to indoor air
- Inhalation of airborne particulates
- Ingestion of soil
- Dermal contact with soil
- External irradiation
- Ingestion of garden produce contaminated by deposition of airborne particulates
- Ingestion of garden produce grown in contaminated soil

A brief discussion of the environmental media associated with the above exposure pathways and the potential fate and transport of chemicals in these media is presented in the following subsections The models associated with these pathways are presented in Section 3 0

2.2 GROUNDWATER

Figure 2-3 illustrates the general conceptual model for groundwater and surface water pathways at OU6 Groundwater flows and contaminants migrate from potentially contaminated soils within an IHSS, into the surrounding Rocky Flats Alluvium and colluvium Contaminated groundwater then migrates out of seeps along valley slopes as surface water or near-surface groundwater in the colluvium to the creeks South and North Walnut creeks, as well as the unnamed northern tributary to Walnut Creek, then transport possible contaminants downstream via surface water processes

2.3 SURFACE WATER

The pathways of interest for surface water are related to ingestion of or dermal contact with surface water containing suspended sediment and/or site-related chemicals potentially transported to surface water Stormwater runoff may transport contaminated soils to surface waters through erosion, with subsequent transport to downstream receptors Surface waters and suspended sediments may also be impacted from the discharge of contaminated groundwater via seeps and springs Figure 2-3 is a conceptual model for groundwater and surface water illustrating these pathways

2.4 AIR

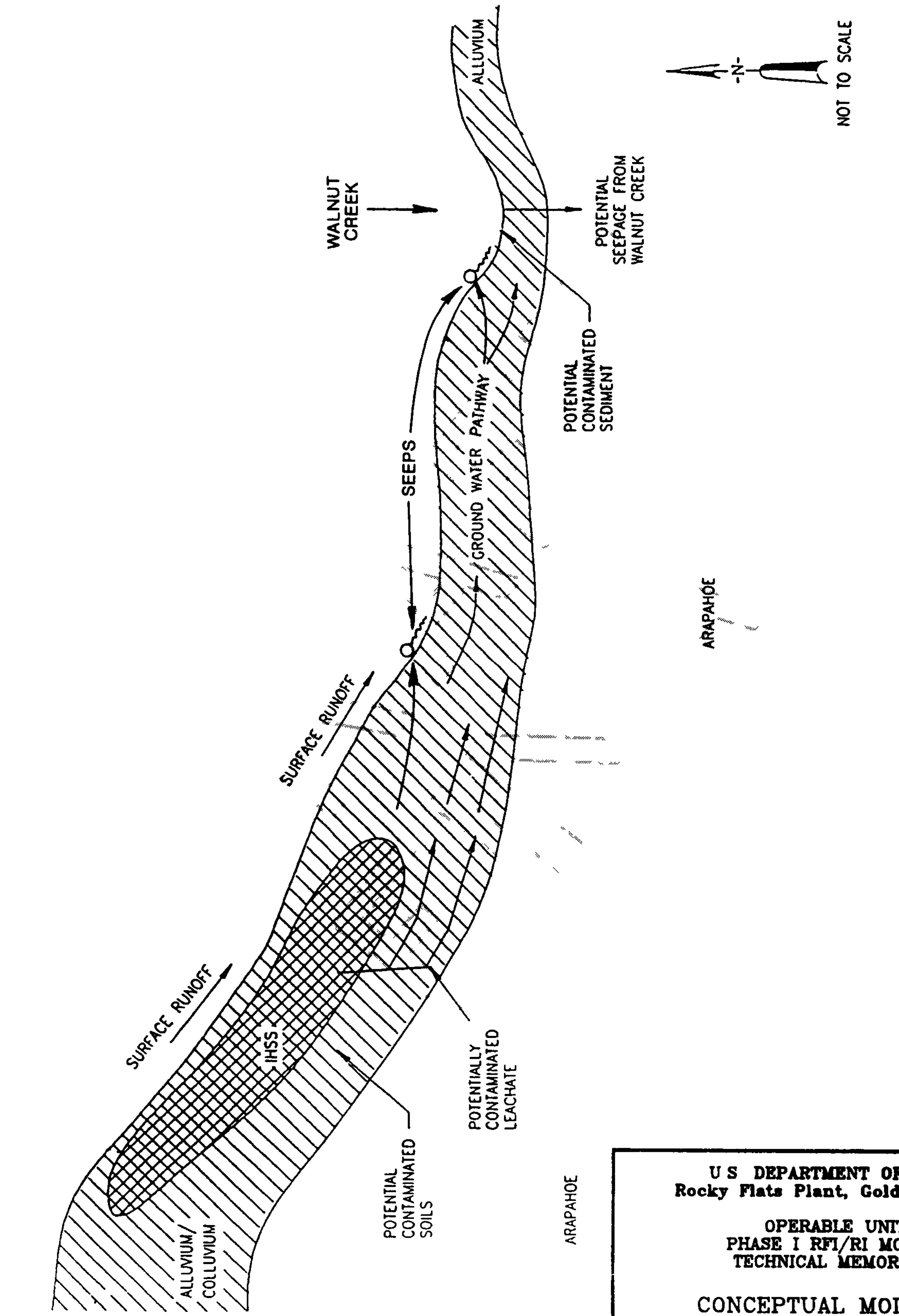
The air emissions and dispersion models selected to assess air contaminant concentrations at sensitive receptors will estimate exposure point concentrations for the exposure pathways associated with air transport shown in Figure 2-1 Volatile organic compounds (VOCs) may be transported through the vadose zone from underlying soils and will be subsequently entrapped within a hypothetical building located on top of OU6 (volatilization into indoor air and subsequent inhalation by a future on-site worker or on-site resident) Chemicals in surface soils may be transported via fugitive dust emissions from OU6 to on-site (inhalation of particulates by the future on-site worker, future on-site resident and future ecological researcher) and off-site exposure points (inhalation of particulates by the current and future off-site residents) Fugitive dust emissions from OU6 may also result in deposition of chemicals in airborne particulates on surface soils and plants Potential chemical intake and corresponding risks associated with these media will also be evaluated A conceptual model for airborne exposure pathways is shown on Figure 2-4

TABLE 2-1
ROCKY FLATS PLANT
OU6
POTENTIALLY COMPLETE EXPOSURE PATHWAYS TO BE QUANTITATIVELY EVALUATED

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Off-site resident	Current	Inhalation of airborne particulates Ingestion of soil contaminated with airborne particulates Dermal contact with soil contaminated with airborne particulates Ingestion of vegetables contaminated by airborne particulates
On-site worker	Current	Inhalation of airborne particulates Ingestion of soil Dermal contact with soil External irradiation from radioactive decay
On-site worker	Future	Inhalation of indoor air with VOCs from groundwater Inhalation of indoor air with VOCs from subsurface soil Inhalation of airborne particulates Ingestion of soil Dermal contact with soil External irradiation from radioactive decay
On-site construction worker	Future	Inhalation of airborne particulates Ingestion of soil Dermal contact with soil External irradiation from radioactive decay
On-site ecological researcher	Future	Surface Water Ingestion (suspended sediment and site-related chemicals potentially transported to surface water) Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water) Inhalation of airborne particulates Ingestion of soil Dermal contact with soil External irradiation from radioactive decay

TABLE 2-1
(Concluded)

Hypothetical on-site resident	Future	Surface Water Ingestion (suspended sediment and site-related chemicals potentially transported to surface water) Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water) Inhalation of indoor air with VOCs from groundwater Inhalation of indoor air with VOCs from subsurface soil Inhalation of airborne particulates Ingestion of soil Dermal contact with soil Ingestion of garden produce contaminated with airborne particulates External irradiation from radioactive decay Ingestion of garden produce grown in contaminated soils
Hypothetical off-site resident	Future	Surface Water Ingestion (suspended sediment and site-related chemicals potentially transported to surface water) Dermal contact with surface water (dissolved-phase constituents of sediment and site-related chemicals potentially transported to surface water) Inhalation of airborne particulates Ingestion of soil contaminated with airborne particulates Dermal contact with soil contaminated with airborne particulates Ingestion of garden produce contaminated with airborne particulates



U S DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

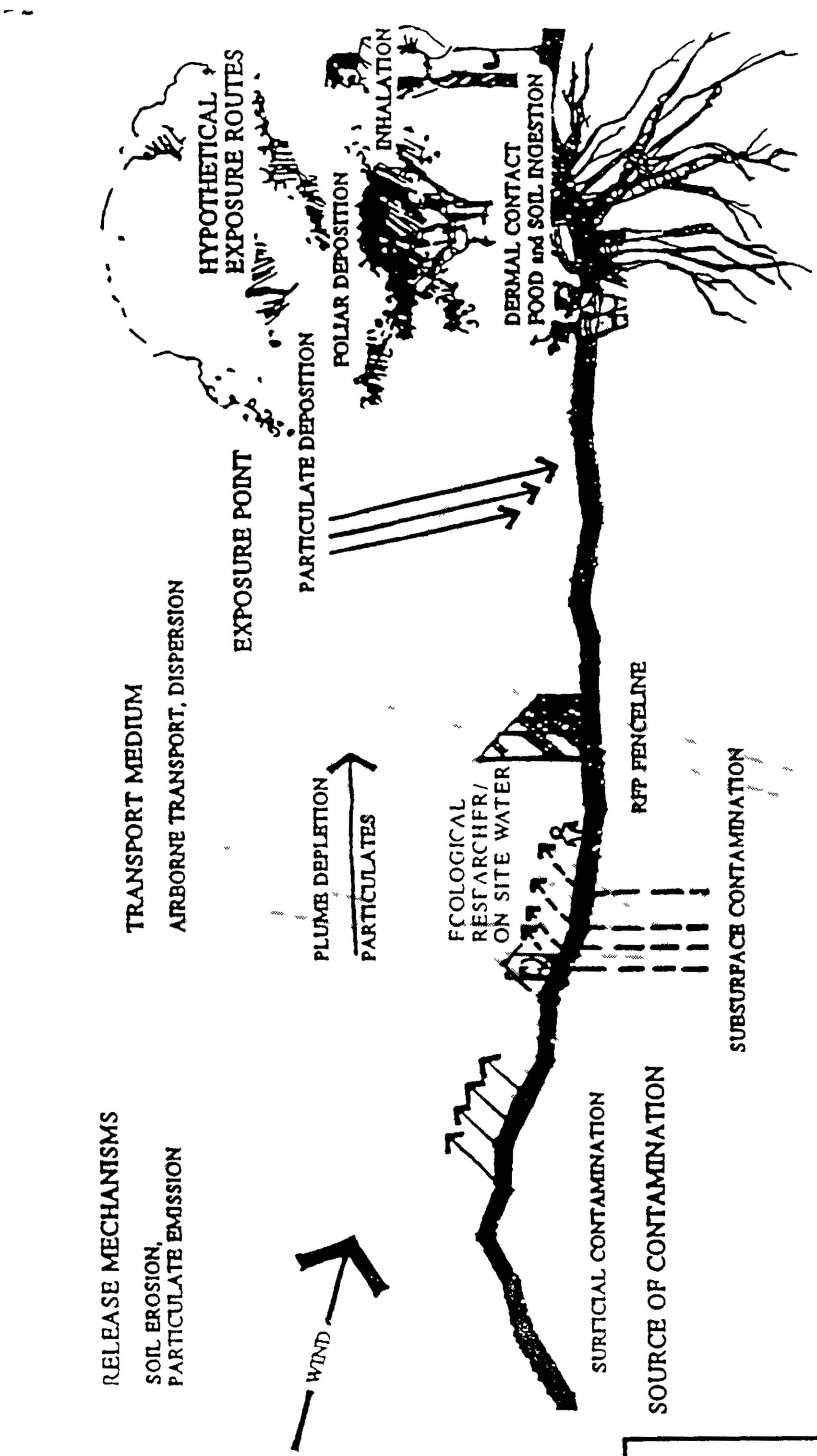
OPERABLE UNIT 6
PHASE I RFI/RI MODELING
TECHNICAL MEMORANDUM

CONCEPTUAL MODEL FOR
GROUNDWATER AND SURFACE WATER

FIGURE 2–3

JUNE 1993

23066E07



U S DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT 6
PHASE I RFI/RI MODELING
TECHNICAL MEMORANDUM

CONCEPTUAL MODEL FOR
AIRBORNE EXPOSURE PATHWAYS

FIGURE 2–4

JUNE 1993

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3.0
MODEL DESCRIPTION

This section specifies the models to be used in characterizing and predicting exposure point concentrations at specific receptor locations for the OU6 risk assessment The considerations for model selection, and the basis for selecting the chosen models are also discussed

The term "model" refers to computer codes or a set of equations that can be used to mathematically represent site conditions and simulate media behavior (e g , groundwater flow) and contaminant fate and transport in the model domain The models will incorporate site-specific data to allow simulation of site-specific conditions and behavior The combination of a computer code and the necessary site-specific data will be referred to as a "site-specific model"

3.1 GENERAL CONSIDERATIONS FOR MODEL SELECTION

According to Bond and Hwang (1988) and van der Heijde and Park (1986), the following issues should be considered when selecting groundwater models for simulating conditions at a site (1) the objectives of the project, (2) the physical and chemical conditions of the site, and (3) the requirements for implementing the models Although the discussions presented by Bond and Hwang, and van der Heijde and Park were directed at groundwater models, it is reasonable to apply the same considerations to surface water and air models

The OU6 modeling objective (issue no 1) is to simulate the transport of contaminants of concern to potential human receptor locations for risk assessment purposes The physical and chemical conditions of the site (issue no 2) have been and are continuing to be characterized as part of the ongoing Phase I RFI/RI process Models selected should be capable of incorporating key on-site transport processes Requirements for implementing the models (issue no 3) include the following (a) the availability of the model, (b) the degree and nature of documentation, (c) the extent of peer review of the model, and (d) the nature of model verification and testing (model verification is the process of verifying that the model results are numerically correct and involves an independent check of the calculations performed by the model)

Based on the issues described above, a set of criteria were developed for selecting the models to be used at OU6 The general criteria are as follows

1 The selected models should be able to incorporate key processes known to occur at the site
2 The selected models should be able to satisfy the objectives of the study
3 The selected models should be verified using published equations and solutions
4 The selected models should be complete and well documented and preferably available in the public domain
5 The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty

These five criteria were used as the basis for selecting the groundwater, surface water, and air models to be used for OU6 The following sections discuss the selected models relative to their ability to satisfy the identified selection criteria.

All mathematical models have limitations and uncertainties associated with assumptions inherent in the models This is true for the models selected for use for OU6 However, it is believed that the selected models presented herein are the most appropriate models available for use for OU6 and that the associated limitations and uncertainties are acceptable

3.2 GROUNDWATER CONTAMINANT FATE AND TRANSPORT MODEL

3.2 1 Introduction

Groundwater contaminant fate and transport modeling will be performed to simulate the movement of dissolved contaminants in groundwater in the saturated zone beneath OU6, and to estimate future dissolved contaminant concentrations in groundwater at identified discharge points This will allow the evaluation of contaminant transport to potential human receptors in the OU6 Human Health Risk Assessment

Contaminant fate and transport in groundwater at OU6 will be simulated using an analytical transport model code For this project ONED3 (Beljin 1989) will be used ONED3 is included in the SOLUTE package of models distributed by the International Ground Water Modeling Center (IGWMC) ONED3 is an analytical transport code and is capable of simulating one dimensional fate and transport of dissolved phase contaminants in a porous medium

Available site-specific and literature data on fate and transport parameters (e g , chemical and radioactive decay, and retardation), source areas, and hydrogeologic conditions will be integrated using ONED3 to simulate the fate and transport of dissolved-phase contaminants in the saturated zone from source areas through the alluvium and colluvium, to discharge points along Walnut Creek   Because several discreet potential contaminant migration pathways are suspected to exist in OU6, several separate ONED3 models may be utilized to simulate groundwater contaminant fate and transport   The results of the site-specific ONED3 models will then be used as inputs to the surface water model.

Contaminant fate and transport will also be evaluated using water balance and chemical mass balance analyses as a check for the reasonableness of the ONED3 model results   Such analyses allow independent evaluation of ONED3 results by estimating seepage discharge rates based on the water balance for OU6, and contaminant loading rates based on chemical mass balance considerations

3.2.2 Model Selection Criteria Evaluation

The ONED3 model code was selected because it satisfies the selection criteria presented in Section 3 1   Water balance and chemical mass balance analyses will allow an independent check of the reasonableness of the ONED3 results   A discussion of how ONED3 meets each of these criteria follows in the order in which the selection criteria are presented in Section 3 1

<u>Selection Criterion 1</u> - The selected models should be able to incorporate key processes known to occur at the site

The ONED3 model code is capable of incorporating key contaminant fate and transport processes known to occur in the alluvium and colluvium at the OU6 site   Those key processes include advection, dispersion, retardation, and decay   The ONED3 model code is capable of simulating the fate and transport of dissolved-phase contaminants in the saturated zone with uniform flow in one direction   The source area and boundary conditions used in ONED3 are relatively simple   This is considered adequate for OU6 because

- The topographic variation and wide separation of source areas across OU6 results in several separate potential contaminant migration pathways from source areas to discharge points Commingling of contaminant plumes from different source areas along complex flow paths is not believed to be prevalent Therefore, separate simplified models are appropriate

- Flow and contaminant migration at OU6 is from source areas to discharge points along Walnut Creek For the purposes of the OU6 risk assessment, a detailed evaluation of migration pathways is not necessary (nor is it possible based on the limited available Phase I data) because simulation of a one-directional pathway across the shortest distance between the source areas and Walnut Creek will provide conservative estimates of contaminant concentrations and associated risk Therefore, one-dimensional flow modeling is appropriate

The water balance and chemical mass balance analyses will incorporate the key process of areal recharge and the principles of conservation of flow and mass.

Selection Criterion 2 - The selected models should be able to satisfy the objectives of the study

ONED3 is capable of satisfying the objective listed in Section 1 1 ONED3 will be used to simulate the movement of dissolved chemical contaminants in groundwater through the alluvium and colluvium and to estimate future concentrations of chemical contaminants where groundwater discharges to Walnut Creek This will then serve as input to the surface water model used to estimate concentrations of chemicals of concern at exposure points for potential human receptors in support of the OU6 Human Health Risk Assessment

Selection Criteria 3 and 4 - The selected models should be verified using published equations and solutions The selected models should be complete and well documented and preferably available in the public domain

ONED3 is widely used analytical contaminant fate and transport model codes Verification of the model codes can be performed by running the codes using input parameters and boundary conditions for which a known solution is available ONED3, as part of the SOLUTE package of models distributed by IGWMC, is readily available with documentation Water balance and chemical mass balance analyses are common computational methods used in hydrologic and contaminant studies

Selection Criterion 5 - The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty

ONED3 is a simple model to set up and use and can be practically and cost-effectively applied to the OU6 site The output from the ONED3 simulations can readily be used to address resolution of uncertainty Water balance and chemical mass balance analyses can also be practically and cost-effectively applied to OU6

3.3 SURFACE WATER MODEL

3.3 1 Introduction

The surface water model will contribute to the overall risk assessment effort by means of several exposure pathways, as shown in Figure 2-1 The watershed/water quality model HSPF9 has been selected for the surface water model HSPF9 outputs will be long term average contaminant concentrations as a function of distance along Walnut Creek Both dissolved and particulate (i e, contaminants associated with suspended solids) will be modeled Standard deviations of these mean concentrations will also be estimated in an uncertainty analysis Model inputs will be time series of precipitation and groundwater seep flows/loads Boundary and initial conditions will also drive the model The time step is anticipated to be daily, or possibly smaller as appropriate to describe rainfall/runoff and erosional processes

HSPF9 (Hydrologic Simulation Program -- Fortran, Version 9) is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants HSPF9 is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions (Ambrose and Barnwell, 1989)

Major processes affecting surface water/sediment pollutant concentrations in OU6 are

- Precipitation/runoff
- Soil erosion and associated pollutant movement
- Stream and pond hydraulics
- Pollutant-specific fate mechanisms

The following sections overview how these major processes are treated by HSPF9

Precipitation/Runoff

Hydrologic simulation is performed using the moisture accounting technique first employed in the Stanford Watershed Model (Figure 3-1) That is, the movement of water into, between, and out of a set of conceptual storages is computed using a fixed time step Rain and snowmelt are subject to interception If that storage is full, infiltration occurs Infiltrated moisture passes to the lower zone or to groundwater storage Excess moisture either remains on the surface or enters flow paths leading to the upper zone or to interflow. The model regards overland flow as equivalent to that along a plane surface of length, slope, and roughness specified by the user Evapotranspiration can occur from any of the storages

Soil Erosion

Soil Erosion is simulated as illustrated in Figure 3-2 Erosion can occur either due to particle detachment from rainfall impact and subsequent washoff or as a result of rill and gully scour

Hydraulics

HSPF9 uses a simple technique for flow routing The catchment stream network is divided into reaches and calculations work from upstream to downstream reaches The stream network can be of any complexity, even including flows that are split and later recombined farther downstream Impoundments (ponds, lakes, reservoirs) are also included although it should be noted that HSPF9 assumes such impoundments to be completely mixed, stratification is not modeled

Pollutant Fate Mechanisms

Several important fate mechanisms will affect the chemicals of concern including partitioning as dissolved/particulate phases, interactions between chemicals in the water column and the sediment bed, and any of a number of chemical-specific, physical/chemical/biological processes (e g , volatilization, biodegradation) HSPF9 can simulate these mechanisms for any generalized quality constituent as illustrated in Figure 3-3

3.3.2 Model Selection Criteria Evaluation

The HSPF9 model described above was selected because it is believed to best satisfy the five selection criteria A discussion of how this model meets each of these criteria follows

Selection Criterion 1 -- The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site

Key processes associated with surface water aspects of OU6 include, as described before, precipitation/runoff, soil erosion and associated pollutant movement, stream and pond hydraulics, and pollutant-specific fate mechanisms HSPF9 has extensive capabilities to incorporate these processes, indeed, HSPF9 is the only watershed hydrology/in-stream water quality model known that integrates these processes in a single computer code

Selection Criterion 2 -- The selected models should be able to satisfy the objectives of the study

The HSPF9 model meets the modeling objective discussed in Section 1 1 To support the risk assessment objective, the model can simulate the transport of chemicals of concern from sources (stormwater runoff, groundwater discharge) to downstream exposure points The models provide the flexibility needed to estimate risks posed by individual sources, i e , the risks associated with either stormwater runoff only or groundwater discharge only

Selection Criteria 3 and 4 -- The selected models should be verified using published equations and solutions The selected models should be complete and well-documented and preferably available in the public domain

HSPF9 has been validated with both field data and model experiments and has been reviewed by independent experts (Ambrose and Barnwell, 1989) It is in the public domain and is distributed and maintained by the US EPA Center for Exposure Assessment Modeling in Athens, GA The original development of HSPF9 began in 1976 and was based on the earlier models Stanford Watershed Model, Agricultural Runoff Model, and the HSP Quality Model

Selection Criterion 5 -- The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty

Although HSPF9 is a comprehensive, mechanistically based model, its modular construct allows it to be tailored to site-specific conditions and objectives It can be configured to be as detailed or as general as the modeling application dictates by activating more or less modular detail This flexibility ensures its "cost-effectiveness"

HSPF9 is purely a deterministic model, no stochastic or uncertainty analysis capabilities exist Uncertainty analysis will be performed outside of the HSPF9 environment by analysis of model prediction errors

3 4 SOIL GAS TRANSPORT MODEL

3.4.1 Introduction

Soil gas transport modeling will be performed if volatile organic compounds are identified in OU6 The modeling will be performed to simulate the diffusion of volatile organic compounds from underlying soil gas as a result of volatilization from soil and groundwater contaminants to the OU6 surface just beneath a hypothetical on-site building The diffusion of volatile organic compounds contained in soil gas from the underlying soil and from the underlying groundwater soil interface is estimated by two different equations An air transport and dispersion model, discussed in Section 3.5, will then be used to estimate airborne VOC concentrations within the building This activity will support and provide input to a Human Health Risk Assessment

3 4.1.1 Volatilization From Underlying Soil

Estimates of volatilization from underlying contaminated soil closest to the OU6 surface will be provided by utilization of the Shen Model, modified by Farino (Farino et al 1983), from Volume II of the Air/Superfund National Technical Guidance Series published by the EPA (EPA 1990) This model is also referred to as the SEAM model, since it is also documented in the Superfund Exposure Assessment Manual (SEAM) (EPA 1988a) This equation is designed for estimating volatilization from underlying soil contamination and the subsequent diffusion of organic vapors to the OU6 surface This equation has been applied in numerous site investigations and has been validated enough to warrant inclusion in published EPA documents

The equation used to estimate the steady-state VOC emission rate is as follows

$$E_i = (AD_i/L)(P_t^{4/3})(C_i)(W_i) \qquad (1)$$

where E_i = emission rate of the contaminant, i (g/sec),
A = surface area (cm^2),
D_i = vapor diffusion coefficient in air (cm^2/sec),
L = surface cap thickness (cm),
P_t = total porosity of the soil cap (cm^3/cm^3),
C_i = saturated vapor concentration of contaminant, i, in the vapor space beneath the surface soil cap (g/cm^3), and
W_i = weight fraction of contaminant, i, in the waste (g/g)

C_i, the saturated vapor concentration, is defined by the equation

$$C_i = \frac{PMW_i}{RT} \tag{2}$$

where P = vapor pressure of the contaminant (mm Hg)
MW_i = molecular weight of the contaminant (gm/gm-mole)
R = molecular gas constant (62,361 mm Hg-cm^3/gm-mole-°K)
T = ambient temperature (°K)

3.4.1.2 Volatilization From Underlying Groundwater

Contributions to surface volatilization emissions from the underlying groundwater will be estimated by the using the following equation, adapted from Thibodeaux and Hwang (1982), as presented in SEAM

$$E_{i(t)} = 2DC_sA/(d + ((2DC_st/C_b) + d^2)^{0.5}) \tag{3}$$

where $E_{i(t)}$ = average emission rate of contaminant i over time t (g/sec)
D = phase transfer coefficient (cm^2/sec)
C_s = the liquid-phase concentration of contaminant i in the soil (g/cm^3)
C_b = bulk contaminant i concentration in the soil (g/cm^3)
A = contaminated surface area (cm^2)
d = depth of the dry zone at sampling time (cm)
t = time measured from sampling time (sec)

This equation assumes that the soil pore spaces connect with the soil surface, the soil conditions are isothermal and that there is no capillary rise of contaminant In addition, sufficient liquid contaminant in the pore spaces is assumed to exist so that volatilization will not deplete the reservoir of contaminant to the point where the rate of volatilization is affected Use of this equation simulates vapor diffusion as being soil-phase controlled and assumes that contaminant concentrations in the soil remain constant until all contaminant is volatilized to the ambient air at the surface Contaminant release is assumed to occur by the "peeling away" of successive unimolecular layers of contaminant from the surface of the "wet" contaminated zone Thus, over time, a "dry zone" of increasing depth at the soil surface and a wet zone of decreasing depth below the dry zone develops Concentrations of the contaminant in the soil immediately surrounding the groundwater areas and within the groundwater are used in this estimation method

The term, D, in the above equation is related to the amount of contaminant i that transfers from the liquid to gas phases and then from the gas phase to diffusion in the surface air and is estimated by

$$D = D_i(P_t^{4/3})\,H_i \tag{4}$$

where D_i = vapor diffusion coefficient in air (cm^2/sec)
P_t = total soil porosity (dimensionless)
H_i = Henry's Law constant in concentration form (dimensionless)

Finally, the term, H_i, is estimated by the below equation

$$H_i = H_i / RT \tag{5}$$

where H_i = Henry's Law constant of the contaminant i (atm-m^3/g-mole)
R = gas constant (8 2 x 10^{5} atm-m^3/g-mole-°K)
T = atmospheric temperature (°K)

The Thibodeaux and Hwang equation assumes that the contaminant concentration in the liquid and gas phases in the soil remains constant until all of the contaminant has been volatilized into the surface ambient air The emission rate, $E_{i(t)}$, is non-zero until the time, t, is equal to a value, t_d, when the soil becomes dry and all contaminant has been volatilized After time t_d, the volatilization emission rate is assumed to be zero The estimation of t_d, in seconds, is obtained from the below equation

$$t_d = ((h^2 - d^2)/2D)(C_b/C_s) \qquad (6)$$

where h = depth from the surface to the bottom of the alluvial aquifer (cm)
d = depth of dry zone at sampling time (cm)
D = phase transfer coefficient (cm^2/sec)
C_b = bulk contaminant i concentration in soil (g/cm^3)
C_s = the liquid-phase concentration of contaminant i in the soil (g/cm^3)

Total surface volatilization emissions are then estimated by adding the contributions calculated from Equations (1) and (3) To estimate the diffusion of surface volatilization emissions through the floor of an on-site building, Darcy's law, modified for gas flow across a permeable structure wall, will be used to estimate the volumetric flow rate induced by surface volatile emissions and ambient air entering into the building confines This volumetric flow rate is estimated by

$$Q_{vol} = -k\,A/v\,(dP/dZ) \qquad (7)$$

where	Q_{vol}	=	volumetric flow rate of induced by soil gas and ambient air
	k	=	intrinsic permeability of soil
	v	=	viscosity of the gas
	dP	=	pressure differential across floor of structure
	dZ	=	thickness of floor

The concentration of the contaminant within the on-site building is then estimated by

$$C_{con} = E_i / Q_{vol} + Q_b \qquad (8)$$

where	C_{con}	=	resultant contaminant concentration within the building
	E_i	=	emission rate of the contaminant below the building floor
	Q_{vol}	=	volumetric flow rate induced by the soil gas
	Q_b	=	volumetric exchange rate within the building

3 4.2 Model Selection Criteria Evaluation

A considerable amount of research and field sampling has been performed to develop models that predict volatilization as a result of soil gas transport The SEAM models were selected because they are believed to best satisfy the selection criteria defined in Section 3 1

Selection Criterion 1 -- The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site

The SEAM models are capable of representing key contaminant processes in estimating soil gas transport The key processes in the SEAM models include treatment of soil gas diffusion to the surface as a result of underlying soil contamination and also the diffusion from areas of soil and groundwater contamination The models allow calculation of volatilization of specific components of a complete waste mixture by assuming that Raoult's Law is applicable A layer of relatively clean and dry soil is assumed to exist between the soil surface and the primary area of underlying soil contamination for the first SEAM equation (Equation (1)) The depth of this relatively clean layer will be assessed by examining site-specific data. Equation (1) assumes that surface VOC emissions are steady-state and do not decay with time This assumption is consistent with site observations that there are underlying areas of soil contamination likely to produce surface VOC emissions at a steady rate for an extended period of time Surface VOC emission contributions from groundwater (Equation (3)) exhibit some dependency with time but will probably not change total surface VOC emissions from a nearly steady state condition

Examination of on-site data suggests that volatilization as a result of soil gas transport will primarily originate from underlying soil contamination areas closest to the OU6 surface and from the underlying groundwater

Selection Criterion 2 -- The selected models should be able to satisfy the objectives of the study

The SEAM models estimate surface volatilization from underlying soil gas with consideration of physical and chemical mechanisms The resulting emission estimates can then be applied to the estimation of exposure point concentrations

Since air contaminant concentrations are directly proportional to emissions estimates, the effectiveness of potential remediation strategies on sources of volatilization that become part of the air exposure pathways can be readily evaluated In addition, the effectiveness of potential remediation strategies can be related to underlying soil and groundwater concentrations since these soil gas transport models estimate VOC emissions in nearly direct proportion to underlying soil (waste) and groundwater concentrations

Selection Criteria 3 and 4 -- The selected models should be verified using published equations and solutions The selected models should be complete and well documented and preferably available in the public domain

The SEAM models for soil gas transport are widely used and well-documented in EPA literature for use in baseline, remedial and post-remedial scenarios Equation (1) has refined the widely accepted Farmer model which was one of the first models developed and used to predict VOC emissions from covered landfills Equation (3) has been widely used for estimation of surface volatilization emissions from old spills and leaks that have migrated below the soil surface The soil gas transport models appearing in the air pathway analysis series have been subject to extensive validation

Selection Criterion 5 -- The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty

These soil gas transport models thoroughly document the proper use of input parameters and demonstrates their use through simulated soil gas transport scenarios Thus, these models can be easily placed into a spreadsheet format to handle multiple volatile organic compounds Since these models are public domain, there are no procurement or licensing costs for their use

3.5 AIR TRANSPORT AND DISPERSION MODELS

3.5.1 Introduction

Air dispersion models simulate the transport of the ambient air volatilization rates estimated from the soil gas transport model and particulate matter to specific exposure points for the air exposure pathways designated in Section 2 0 Two different air dispersion models will be utilized according to the following scenarios

- The transport of volatile organic compounds into a building located on the surface of OU6 will be estimated through the use of a box model

- The transport of particulate matter to on-site receptors both as air contaminant concentrations and air deposition values will be examined through the use of a box model

- The transport of particulate matter to off-site receptors (i e , future and current off-site resident) both as air contaminant concentrations and air deposition values will be evaluated through the use of FDM

The air contaminant concentration and deposition values provided by the air transport models will support and provide input to the Human Health Risk Assessment Air dispersion modeling will be performed in accordance with procedures described in Volume IV, Procedures for Dispersion Modeling and Air Monitoring for Superfund Air Pathway Analysis, Air/Superfund National Technical Guidance Study Series (EPA-450/1-89-004) and the Guideline on Air Quality Models (EPA-450/2-78-027R) The model for on-site receptors will be a conventional box model that is used widely for immediate exposure scenarios. The models for off-site receptors will be based on Gaussian dispersion and are models approved by EPA Both models will provide ambient air contaminant concentration and deposition values at the previously defined exposure points

3.5.2 Model Selection Criteria Evaluation

The models selected to be most appropriate for OU6 are a conventional box model for on-site impacts and the Fugitive Dust Model (FDM) for estimation of airborne particulate concentrations and deposition at off-site receptor locations These models are believed to best satisfy the selection criteria presented in Section 3 1 The box model will be used to model transport of volatiles to a future on-site worker or future resident in a building, and will also be used to model ambient particulate impacts to a future industrial worker, a future on-site resident, and a future ecological worker also located on-site The FDM will be used to model transport of airborne particulate, both as air contaminant concentrations and as deposition values, at the current and future resident exposure points A discussion of how each air transport model meets each of these criteria is presented below

<u>Selection Criteria 1</u> - The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site

The box model and the FDM air models are capable of representing key contaminant processes in estimating air transport and dispersion of air emissions originating from OU6 The box model uses conservation of mass principles to estimate resultant air concentrations for an input emission rate dispersed within a fixed volume with an air exchange rate proportional to the air flow (wind speed) traversing the volume The box model used for estimating on-site impacts considers the dilution of air emissions within a given volume, defined by the horizontal dimensions of a contaminated area or of an enclosed structure (i e , building) and the height determined either by surface turbulence or the confined height of a structure The air exchange rate is dependent upon the utilized wind speed or volumetric air exchange rate, if within the confines of a building The FDM uses Gaussian plume transport and dispersion algorithms with a gradient-transfer deposition and settling algorithm to simulate air contaminant concentration and values from non-point sources at distances corresponding to off-site receptors The FDM was specifically developed for fugitive particulate matter modeling applications (especially wind erosion) The FDM has the capability of assessing up to 100 area sources, 200 receptor points, and 20 particle size classes FDM is unique in that it can assess rectangularly shaped area sources, not just square or circular This capability allows FDM to model area sources using a geometry that more closely approximates their actual shape FDM can utilize constant as well as variable emission rates FDM can also calculate ground-level concentrations either with settling and deposition functions (as with particulate matter), or without (as with gaseous contaminants) The FDM has the capability to model for short (1-, 3-, 8-, and 24-hour) and long (annual) term averaging periods, and uses meteorological data in either hourly or Stability Array (STAR) formats

By using the AP-42 (EPA 1988c) emission models (EPA 1988c) for fugitive particulate emission estimation, the FDM model is not required to apply correction factors to account for varying types of land surfaces However, the FDM will allow for the direct computation of the contaminant emission rate as a function of the wind speed or allow the user to input a constant emission rate In this way, the model can assess short-term and long-term impacts

Receptor locations are evaluated by their relative distance (x,y) from the source and their elevation (z) (EPA 1988b)

<u>Selection Criteria 2</u> - The selected models should be able to satisfy the objectives of the study

Output from these models either as air contaminant concentrations or as deposition values at the designated exposure points will provide input for the assessment of human health risks The ability of these models to simulate the transport and dispersion of particulate supports the objective of the modeling effort

The multiple compounds potentially identified as contaminants of concern will be easily handled by the selected air dispersion models through a multiplicative factor (the ratio of a specific compound source term to a unit emission rate) that is multiplied by the estimated ambient impacts from a unit emission rate (i e , because of the linear relationship of air concentration to input emission rate) In addition, each of these models can be used to evaluate the effectiveness of potential remediation strategies by simply varying the source term as a function of the remediation strategy being examined

Selection Criteria 3 and 4 - The selected models should be verified using published equations and solutions The selected models should be complete and well documented and preferably available in the public domain

Both models are recommended by EPA as the most representative methods for determining respective transport and dispersion characteristics for VOCs and inorganic metals, semi-volatiles and radionuclides in particulate form These models have been used extensively on both non-remedial and remedial studies (the FDM model has undergone considerable validation and verification)

Selection Criterion 5 - The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

Both models are readily available since they are public domain models and do not require special procurement or licensing costs Their use is well-documented and both models are designed to execute on PC-compatible computers Support for use of these models is also readily available Their relative ease of use and wide acceptance of the modeling results makes them preferable over other available models

3.6 SUMMARY OF PARAMETER VALUES

This section presents a summary of the data currently available to estimate model parameter values for groundwater, surface-water, and air modeling Where available, site-specific data collected during the Phase I RFI/RI investigations or earlier studies will be used If site-specific data are not available, published literature values will be used in the modeling activities

Tables 3-1, 3-2, 3-3, and 3-4 present a summary of data currently available to estimate model parameters The available data were compiled based on a review of previous investigations and the data currently available from the Phase I RFI/RI investigation, or general literature In the case of chemical parameter values, development of the list of contaminants of concern (COCs) has not been completed at this time Therefore, it is not possible to summarize chemical parameter data for each of the COCs at this time Chemical parameter data will be compiled following EPA approval of the COC technical memorandum to be submitted later

The data presented in Tables 3-1, 3-2, 3-3, and 3-4 are preliminary and, in some cases, are not site specific The data values or ranges of values are not intended to be fixed or final The ranges are presented to convey what is currently known of the potential variability in parameter values that may be used in the models

The meteorological data to be used will be one year hourly meteorological data set from 1991 or 1992 from the ten meter level of the West Buffer Zone 61 meter tower The Rocky Flats Plant meteorological monitoring program includes one 61 meter (m) tower instrumented with Prevention of Significant Deterioration (PSD) quality equipment at three levels (10 m , 25 m , and 60 m.) located on the west side of the plant property, outside of the plant security fence The 10 m data will be merged with concurrent mixing height data from Stapleton International Airport Stability class will be determined from sigma theta and wind speed measurements obtained form the West Buffer Zone meteorological database Maximum wind speed data from this site may also be used to estimate wind erosion emissions

TABLE 3-1

PARAMETER VALUES FOR GROUNDWATER MODELING

Parameter	Units	Range of Values	Source
Properties of Colluvium/Alluvium			
Hydraulic Conductivity	cm/sec	10^{5} - 10^{3}	Freeze and Cherry (1979) and OU6 and OU2 site-specific data
Effective Porosity	%	3 - 10	OU6 and OU2 site-specific data
Bulk Density	lbs/ft^3	94-130	Das (1985) and OU6 and OU2 site-specific data
Retardation Factor	Dimensionless	1-10	OU2 site-specific data for specific organic chemicals
Biodegradation Half-Life	Days	7-1825	Howard, et al (1991) for specific organic chemicals

TABLE 3-2

SURFACE WATER MAJOR PARAMETER VALUES

Parameter	Units	Range of Values*
Precipitation/Runoff		
Nominal soil moisture storage (LZSN,UZSN)	inches	01 - 100
Infiltration capacity index (INFILT)	in/hr	0001 - 100
Groundwater recession rate (AGWRC)	per day	001 - 1 0
Interception storage capacity (CEPSC)	inches	0 - 10
Trade-off between interflow and surface runoff (INTFW)	none	min of 0 (no max)
Interflow recession parameter (IRC)	per day	0 - 1 0
Air temperature below which precipitation will be snow (TSNOW)	deg F	30 - 40
Fraction of the land segment which is shaded from solar radiation (SHADE)	none	0 - 1
Interception storage capacity of an impervious surface (RETSC)	inches	0 - 10
Soil erosion		
Initial storage of detached sediment (DETSB)	tons/acre	min of 0 (no max)
Fraction of detached sediment which reattaches each day (AFFIX)	per day	0 - 1
Flux to/from atmosphere from/to detached storage (NVSI)	lbs /acre-day	none
Coefficient for detached sediment washoff (KSER)	none	0 - 1
Coefficient for soil scour (KGER)	none	0 - 1
Hydrodynamics		
Median diameter of bed sediment (DB50)	inches	0001 - 100
Channel characteristics as functions of the water surface elevation		
depth	feet	none
surface area	sq feet	none
volume	cubic feet	none

TABLE 3-2

SURFACE WATER MAJOR PARAMETER VALUES

Parameter	Units	Range of Values*
Contaminant Fate		
Ratio of volatilization rate to oxygen reaeration rate (CFGAS)	none	min of 0 (no max)
Partitioning coeffecient between dissolved and suspended states (KDJ)	none	0 - 1
First-order biodegradation rate constant (KBIO)	per day	0 - 1

* Parameter ranges were obtained from the HSPF User's Manual, 1984

OU6 site-specific data will be used where available

TABLE 3-3

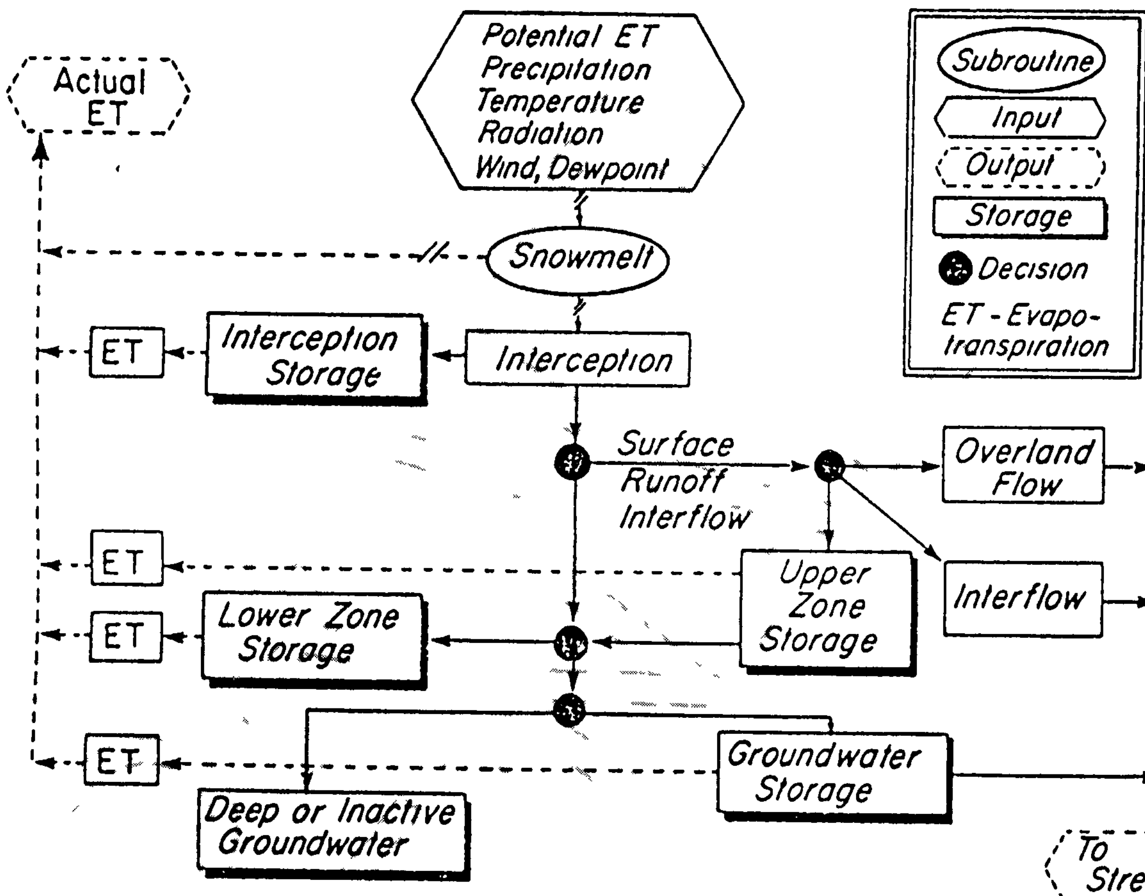
PARAMETER VALUES FOR SOIL GAS MODELING

Parameter	Units	Range of Values	Source
Surface Area of IHSS	cm^2	10^6 - 10^{10}	Phase II RFI/RI Workplan (DOE 1992a)
Surface Cap Thickness	cm	10^1 - 10^2	OU6 site-specific data
Soil Cap Air-filled Porosity	%	25-35	OU6 site-specific data
Vapor Diffusion Coeff in Air	cm^2/sec	10^{2} -10^{1}	Compound-specific, SEAM (1988a) or Lyman (1982)
Thickness of contaminated soil	cm	10	OU6 site-specific data
Weight fraction of contaminant in waste	g/g	10^{9}-10^{5}	OU6 site-specific data
Intrinsic permeability of soil	cm^2	10^{9}-10^{7}	OU6 site-specific data
Liquid-phase concentration of contaminant	g/cm^3	10^3-10^0	OU6 site-specific data

TABLE 3-4

PARAMETER VALUES FOR AIR TRANSPORT AND DISPERSION MODELING

Parameter	Units	Range of Values	Source
Joint frequency distribution of stability class, wind speed and direction	Unitless	fraction of one, total sum of all entries is one	RFP Site Environmental Report for 1990 (EG&G 1991a)
Mean annual morning and afternoon mixing heights	m	250-4000	Data for Denver, CO from Holzworth (1972)
Particle size	μm	1-80	OU6 site-specific data
Particle size distribution	Unitless	fraction of one, total sum of all entries is one	OU6 site-specific data
Contaminated area (surface dimensions)	m^2	10^3 - 10^4	OU6 site-specific data
Ground Coverage	%	0-100	Aerial photos, on-site (unvegetated area) observations
Receptor location, above source, distance from source	m	1-10^3	Scaled maps of elevation of study area
Surface roughness	cm	1-100	Site observations correlated with documented criteria on assigning appropriate surface roughness value



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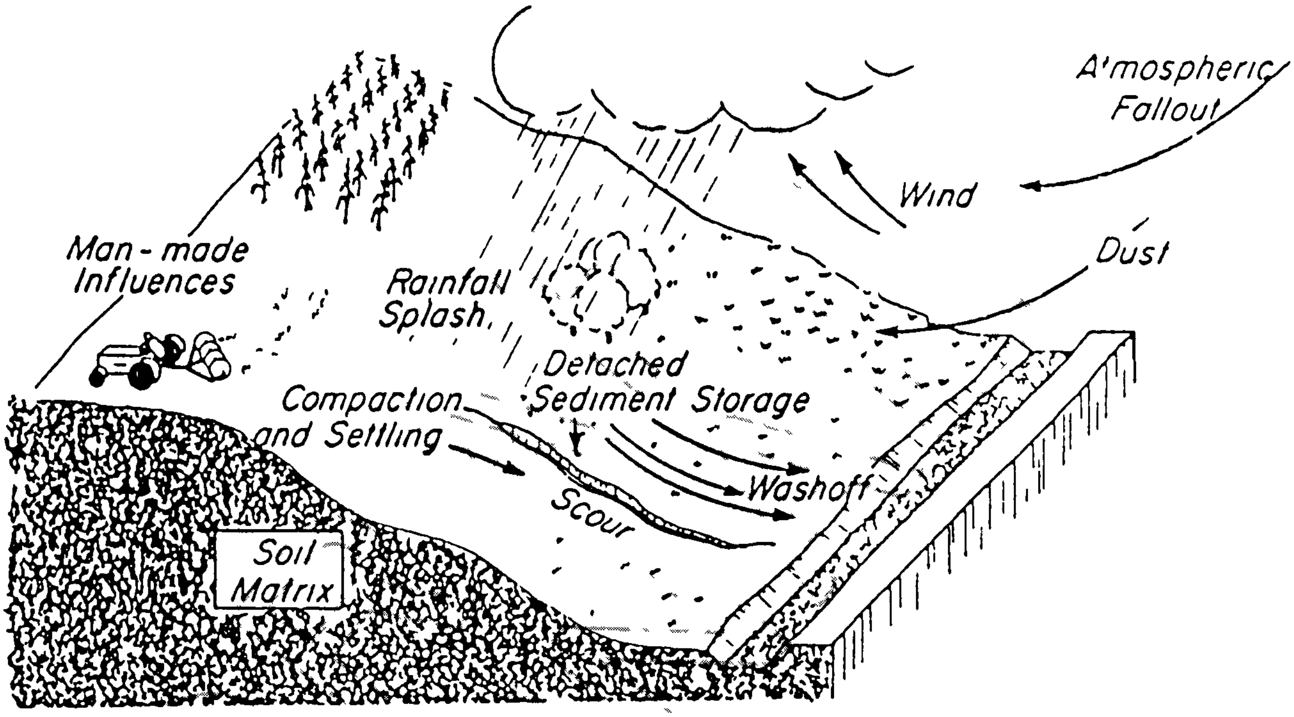
PHASE I RFI/RI MODELING
TECHNICAL MEMORANDUM

HSPF9
PRECIPITATION/RUNOFF PROCESSES

FIGURE 3-1

JUNE 1993

23066E09



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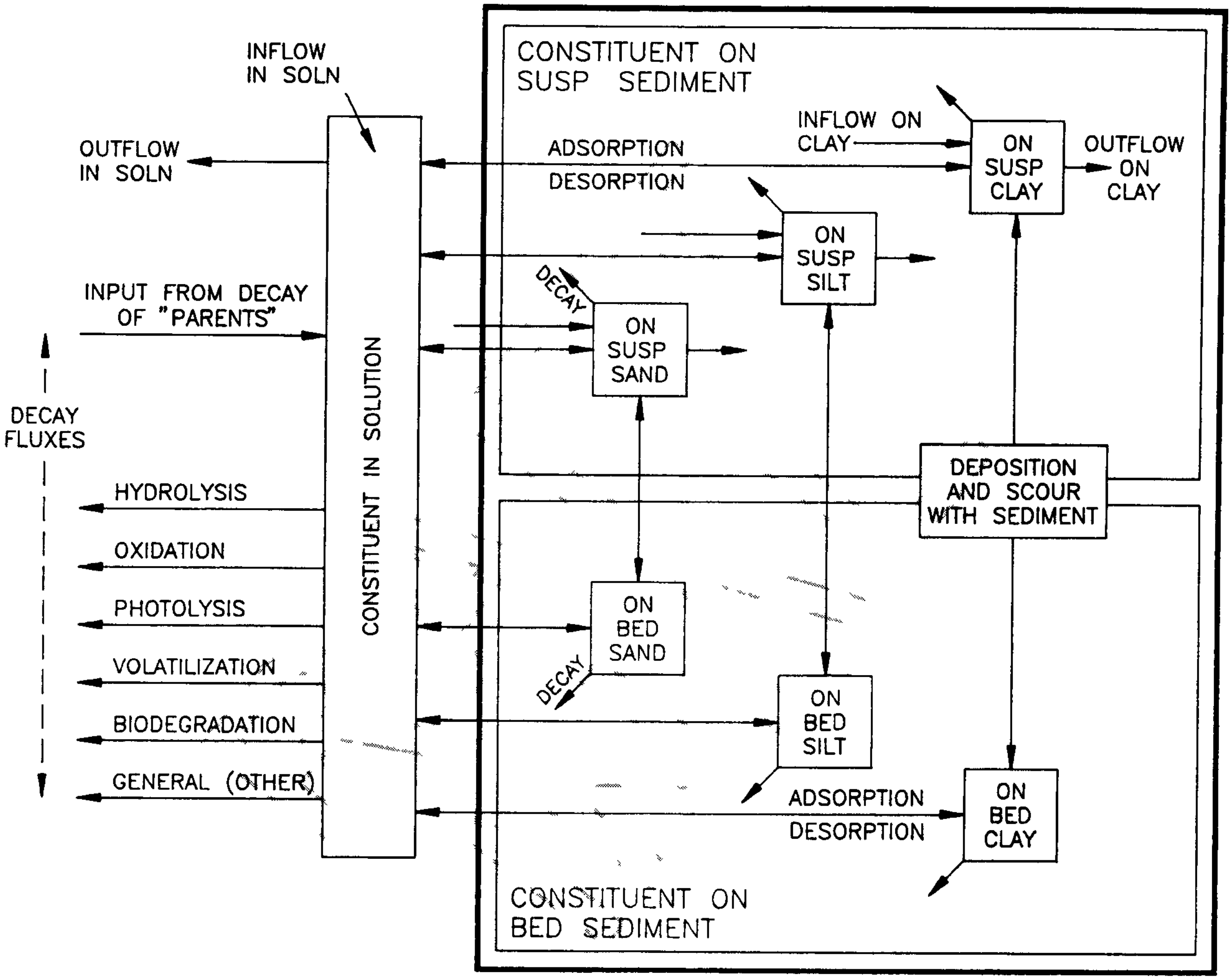
TECHNICAL MEMORANDUM

HSPF9
SOIL EROSION PROCESSES

FIGUPE 3-2

JUNE 1993

23066E10



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TECHNICAL MEMORANDUM

HSPF9
POLLUTANT FATE MECHANISMS

FIGURE 3-3

JUNE 1993

23066E11

4.0
SUMMARY

In order to model the fate and transport of contaminants at OU6 to specific exposure point locations for the Human Health Risk Assessment, several models have been evaluated for application to groundwater, surface water, and air modeling Model selection was based on the following five criteria

1 The selected models should be able to incorporate key processes known to occur at the site
2 The selected models should be able to satisfy the objectives of the study
3 The selected models should be verified using published equations and solutions
4 The selected models should be complete and well documented and preferably available in the public domain
5 The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty

The following models were selected to meet the requirements of the modeling study

- The ONE3D analytical model for contaminant fate and transport in groundwater
- The HSPF9 model for surface water fate and transport
- The SEAM models for soil gas fate and transport, a box model for on-site ambient air contaminant fate and transport, and FDM for off-site ambient air contaminant fate and transport of OU6 source air emissions

Data currently available for use as input for the modeling activities were evaluated Tables 3-1, 3-2, 3-3 and 3-4 summarize the data currently available to estimate model parameters Data from the Phase I RFI/RI investigation will also be used in the modeling effort once those data become available

5.0
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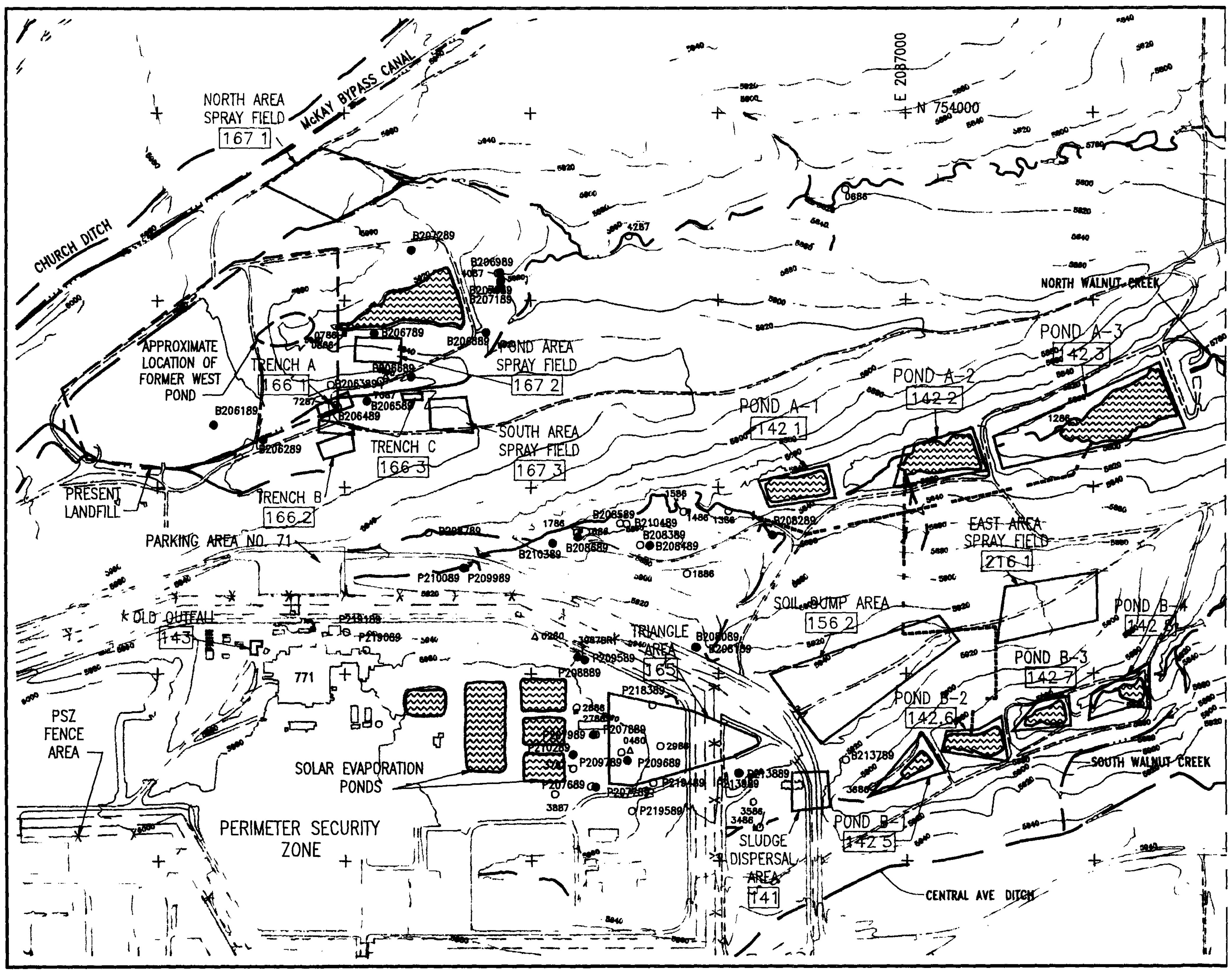

MATCHLINE
(SEE FIGURE 1-2 [2 OF 2])

N

0 000 000
SCALE

EXPLANATION

- INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) IN OPERABLE UNIT 6
- 115 IHSS REFERENCE NUMBER
- PERIMETER SECURITY ZONE
- DIRT ROAD
- 5786 EXISTING ALLUVIAL GROUNDWATER MONITORING WELL
- B208189 EXISTING BEDROCK GROUNDWATER MONITORING WELL
- 0181 EXISTING PRE 1986 GROUNDWATER MONITORING WELL
- 1486 EXISTING PRE 1988 BEDROCK GROUNDWATER MONITORING WELL
- INTERMITTENT STREAM
- A-1 BYPASS (UNDERGROUND PIPELINE)
- UNDERGROUND PIPELINE FROM POND B-2 TO POND A-2

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LOCATION MAP OF INDIVIDUAL HAZARDOUS SUBSTANCE SITES MONITORING WELLS & DIVERSION STRUCTURES ALONG NORTH & SOUTH WALNUT CREEKS

FIGURE 1-2 (1 OF 2) JUNE 1993

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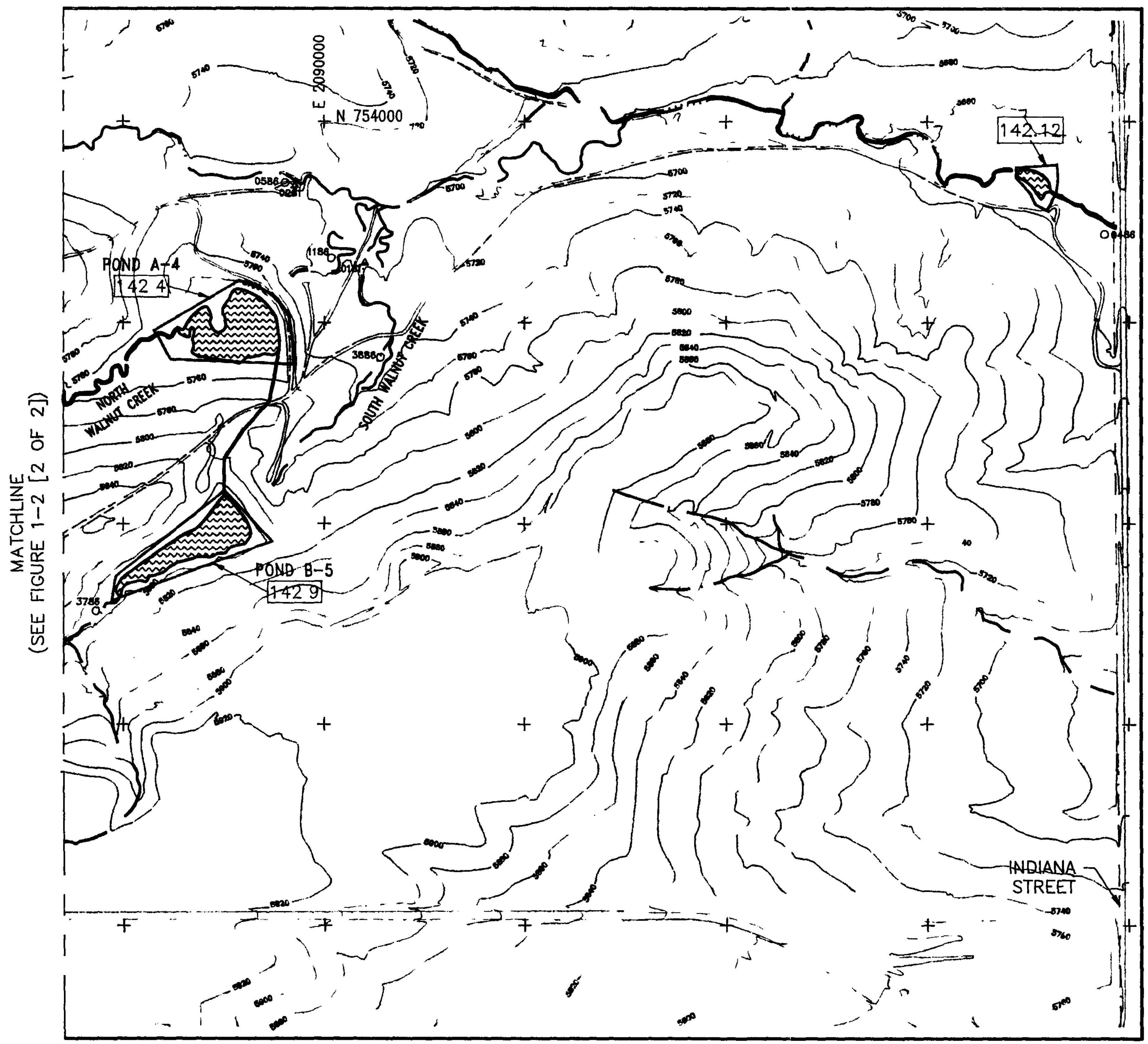

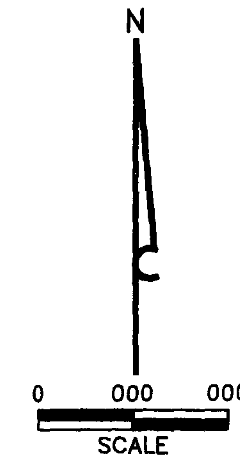

EXPLANATION

- INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) IN OPERABLE UNIT 6
- 115 IHSS REFERENCE NUMBER
- PERIMETER SECURITY ZONE
- DIRT ROAD
- 5786 EXISTING ALLUVIAL GROUNDWATER MONITORING WELL
- B208189 EXISTING BEDROCK GROUNDWATER MONITORING WELL
- 0181 EXISTING PRE-1986 GROUNDWATER MONITORING WELL
- 1486 EXISTING PRE-1988 BEDROCK GROUNDWATER MONITORING WELL
- INTERMITTENT STREAM
- TRANSFER LINE FROM POND B-5 TO POND A-4

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TECHNICAL MEMORANDUM

LOCATION MAP OF INDIVIDUAL HAZARDOUS SUBSTANCE SITES MONITORING WELLS, & DIVERSION STRUCTURES ALONG NORTH & SOUTH WALNUT CREEKS

FIGURE 1-2 (2 OF 2) JUNE 1993

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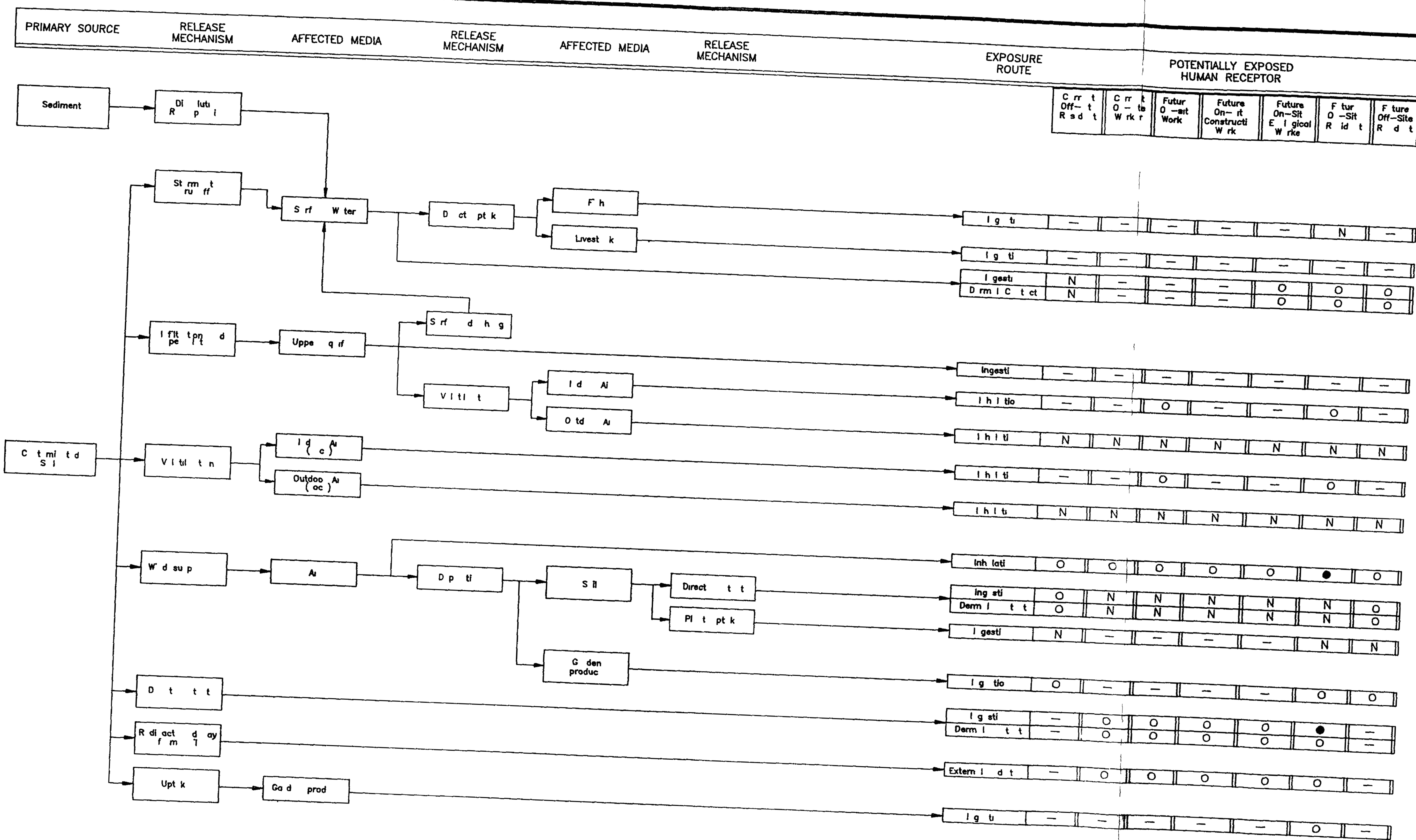

LEGEND
- ● Significant Potential Exposure Pathway
- O Insignificant Potential Exposure Pathway
- N Negligible Exposure Pathway
- — Incomplete Exposure Pathway

NOTE
Significant and insignificant potential exposure pathways will be evaluated in the risk assessment

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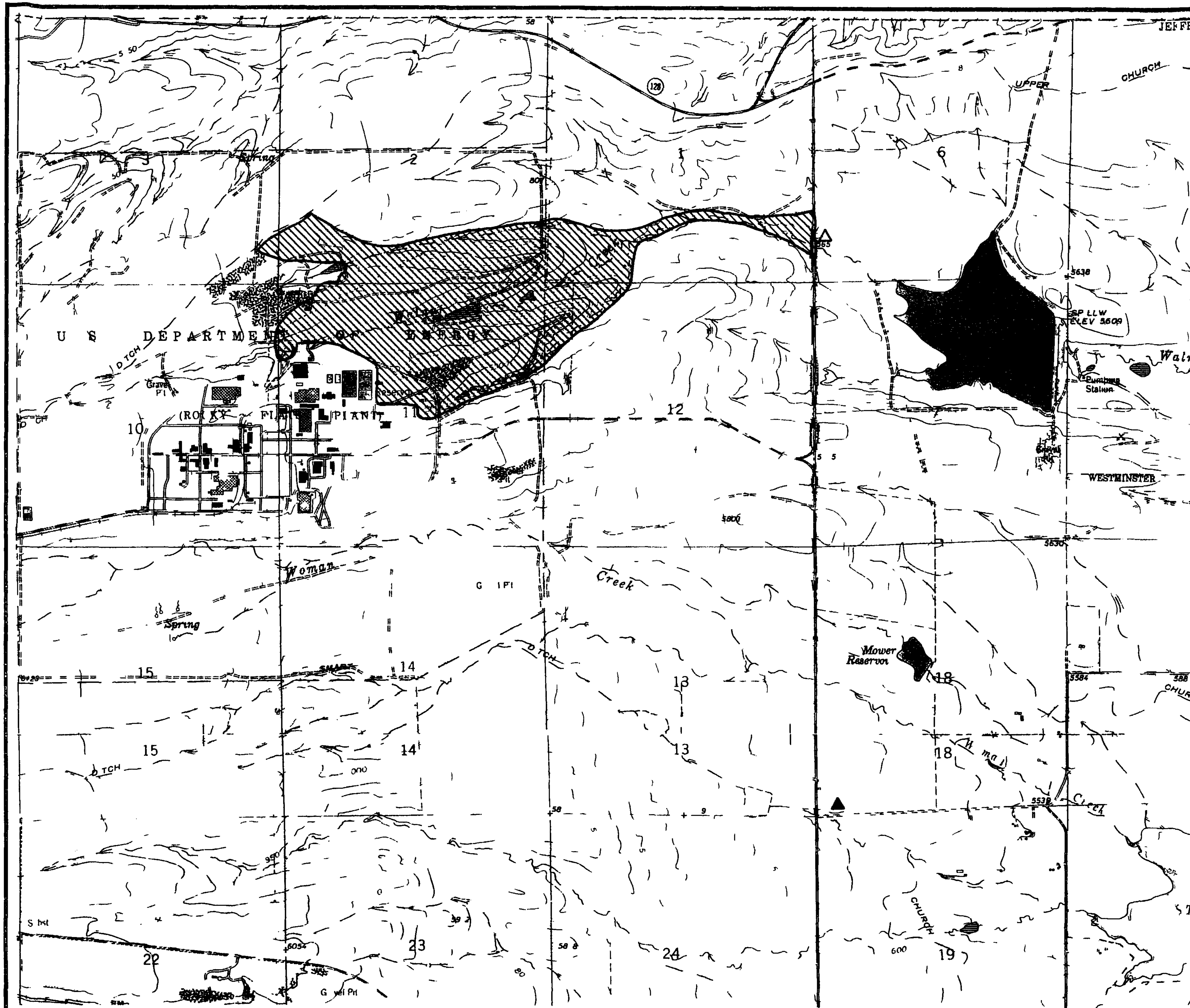
CONCEPTUAL SITE MODEL
POTENTIAL HUMAN EXPOSURE PATHWAYS
ROCKY FLATS OU6

FIGURE 2-1 JUNE 1993

23066E05



LEGEND

▲ EXPOSURE POINT CURRENT RESIDENT

△ HYPOTHETICAL FUTURE RESIDENT EXPOSURE POINT

▨ EXPOSURE AREA CURRENT ON SITE WORKERS FUTURE ON SITE WORKERS ON SITE ECOLOGICAL RESEARCHERS ON SITE RESIDENTS

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POTENTIAL HUMAN
RECEPTOR LOCATIONS
ROCKY FLATS OU6

FIGURE 2-2

JUNE 1993